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THE HUNTLEY MOUNTAIN FORMATION: CATSKILL-TO-BURGOON TRANSITION IN NORTH-CENTRAL PENNSYLVANIA

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COVER View looking south down Pine Creek gorge from the type section of the Huntley Mountain Formation, above the village of Waterville, Pennsylvania. Tiered topography typical of the Huntley Mountain Formation is visible on the steep hillside just to the left of Pine Creek where it turns west out of view.

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PREFACE

An understanding of stratigraphy is fundamental to all other investigations of sedimentary rocks, including mapping, evaluation of sedimentary mineral resources and fuels, and prediction of groundwater movement through sedimentary rocks. In working out the three-dimensional framework of sedimentary rock units, names must ultimately be applied to those units. Formations that are formally named are defined on the basis of physical characteristics. The age of a formation is estimated through the study of fossils, but is not used to define the formation. The new formation name established in this report is applied to a sequence of strata in north-central Pennsylvania that formerly carried names that had age or time implication. The stratigraphic framework described in this report should provide a sound basis for detailed mapping and attendant geologic investigations in north-central Pennsylvania.

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THE HUNTLEY MOUNTAIN FORMATION: CATSKILL-TO-BURGOON TRANSITION IN NORTH-CENTRAL PENNSYLVANIA

by
Thomas M. Berg and William E. Edmunds[1]

ABSTRACT

The Huntley Mountain Formation consists of the dominantly nonmarine clastic succession in north-central Pennsylvania that is transitional between the Catskill Formation and the Burgoon Sandstone. This new stratigraphic name replaces the names "Oswayo" and lower "Pocono," which were applied to the succession in a partly time-stratigraphic sense. The confusion between rock-stratigraphic and time-stratigraphic nomenclature in this region arose many years ago. In 1934, Caster correctly separated the two approaches when he developed the magnafacies concept. The rock interval named herein is essentially the same as Caster's "Tioga magnafacies," but that name was never used formally, and was never applied in mapping. The Huntley Mountain Formation includes the informal "lower sandstone sequence" and "upper sandstone sequence" mapped by Colton (1963b).

The Huntley Mountain Formation comprises greenish-gray to light-olive-gray sandstones, and some thin beds of grayish-red siltstone or clay shale. This formation consists of a 200–m– (650–ft–) thick transition in which the lower sandstones are similar to the Catskill sandstones, and the upper sandstones are similar to the overlying Burgoon sandstones. The Huntley Mountain sandstones are crossbedded or planar bedded, and display natural fragmentation which is typically slabby to flaggy. The sandstones are immature phyllarenite to immature subphyllarenite. Minor lithic components in the Huntley Mountain Formation include intraformational conglomerate ("calcareous breccias" of early workers), extraformational conglomerate (including the conglomerate at Cedar Run), nonred fine clastics, and pisolith beds. The lithologies in the Huntley Mountain are arranged in fining-upward cycles which yield a tiered geomorphic expression that is easily recognizable on aerial photographs.

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The Huntley Mountain Formation is separated from the underlying Catskill Formation at the highest occurrence of grayish-red sandstone in the Catskill. It is separated from the overlying Burgoon Sandstone by the change from light-olive-gray, fine-grained, flaggy sandstone of the Huntley Mountain to buff, medium-grained, slabby or blocky sandstone of the Burgoon. The Huntley Mountain is the approximate lateral equivalent of the Spechty Kopf Formation of northeastern Pennsylvania and the Rockwell Formation of south-central Pennsylvania, but differs from them lithologically in that it is composed dominantly of greenish-gray flagstone and minor red shale. An arbitrary cutoff defines the western limit of this sequence where it grades laterally by facies change into the dominantly marine Oswayo-through-Shenango succession.

The Huntley Mountain contains fossil plants which are questionably identified as *Archaeopteris* and *Adiantites*; the Mississippian-Devonian boundary, which might be defined by differentiating these two genera, probably occurs within the formation, but more research needs to be done to accurately identify the plants. Fossil brachiopods occur at the horizon of the conglomerate at Cedar Run; these are similar to *Syringothyris*, which is thought to mark the Mississippian-Devonian boundary. Fossil bivalves, fossil conchostracans, and trace fossils also occur.

The authors believe that this new formation represents a depositional environment characterized by meandering rivers that carried a greater sand input than the rivers that deposited the underlying Catskill Formation. The meandering may have been somewhat more ephemeral than the Catskill rivers, and may have been transitional to the braided-river system that deposited the overlying Burgoon sandstones. The Huntley Mountain Formation is punctuated near the middle by the conglomerate at Cedar Run, which represents a very rapid marine transgression.

The flagstone in the Huntley Mountain appears to be the most important economic resource, but some of the claystone and clay shale may have marginal importance. Mapping of marker beds in this formation (such as the conglomerate at Cedar Run) may lead to considerable refinement of detailed structure in north-central Pennsylvania. At present, no uranium mineralization has been detected in the Huntley Mountain.

INTRODUCTION

The purpose of this report is to formally name and describe the sequence of nonmarine rocks in north-central Pennsylvania that lies between the Catskill Formation (Upper Devonian) and the Burgoon Sandstone (Mississippian). The new formation named herein was recognized during compilation of the 1980 edition of the geologic map of Pennsylvania (Berg and others, 1980). This new stratigraphic unit, called the Huntley Mountain Formation,

was formerly treated as a combination of the "Oswayo" Formation and the lower "Pocono" Formation. The present authors recognized that this terminology had been applied in the past in a time-stratigraphic sense, and not in a strictly rock-stratigraphic sense. In particular, previous workers had separated the unit by mapping the Mississippian-Devonian systemic boundary, and their method of recognition was not purely rock-stratigraphic. Their emphasis was on the *age* of the rocks.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance provided by W. D. Sevon of the Pennsylvania Geological Survey in measuring the type section of the Huntley Mountain Formation. His careful attention to field observations and his willingness to divert the attention of rattlesnakes are greatly appreciated. Sevon mapped the eastern limits of the Huntley Mountain in Sullivan and Wyoming Counties for the 1980 state geologic map. The authors also wish to thank Dr. Sevon for his helpful criticisms of the manuscript.

The authors express their appreciation to George W. Colton (retired) of the U. S. Geological Survey, not only for providing access to his detailed field records for north-central Pennsylvania, but also for the initial work that he did in the 1960's in subdividing the stratigraphic sequence in that part of the Commonwealth.

STRATIGRAPHIC NOMENCLATURE

Facies Concepts

For almost a century and a half, the sedimentary rocks exposed in northern Pennsylvania and southern New York have undergone a nomenclatural history that has perhaps been one of the most intricate and complicated in the annals of American stratigraphy. The Middle Devonian, Late Devonian, and Mississippian strata in this region display a classical, textbook example of laterally interfingering sedimentary facies and subtle facies changes.

Dunbar and Rodgers (1957, p. 137-140) cited the history of stratigraphic names applied to the great "Catskill Delta" and associated Middle and Upper Devonian rocks of New York and Pennsylvania as one of the best examples of development of the facies concept in the field of stratigraphy. They recounted the early stratigraphic work of Hall, Conrad, and Vanuxem in the 1840's, and the refinements and early recognition of sedimentary facies by Williams, Prosser, and Clarke in the 1880's and 1890's. They emphasized the later work of Chadwick and Cooper in the 1920's and 1930's, when it was clearly recognized that geologic time boundaries transect rock-stratigraphic units.

The development of the facies concept in stratigraphy went hand-in-hand with development of the concept of time-stratigraphic units. According to the American Commission on Stratigraphic Nomenclature (1970, p. 13), "A time-stratigraphic unit is a subdivision of rocks considered solely as the record of a specific interval of geologic time." Ideally, a time-stratigraphic unit is bounded by isochronic horizons.

Because the early research on the Devonian and Mississippian strata in Pennsylvania and New York received as much attention from a paleontologic and time-stratigraphic standpoint as from a lithologic or rock-stratigraphic standpoint, there arose over the years a confusion of stratigraphic names and methods of mapping that involved both time-stratigraphic units and rock-stratigraphic units.

The American Commission on Stratigraphic Nomenclature (1970, p. 5) makes it clear that concepts of time should not be used in defining a rock-stratigraphic unit. The Pennsylvania Geological Survey publishes bedrock geologic maps showing rock-stratigraphic units, and does not intend to confuse the boundaries of those units with apparent divisions of geologic time.

At the inception of the revision of Pennsylvania's state geologic map in 1975, the authors checked the origin and usage of the stratigraphic names applied to the Upper Devonian and Mississippian rocks of northern and western Pennsylvania, and spent a large amount of time in the field examining the rock sequence from the standpoint of mappability. The nomenclature was found to be clearly time-stratigraphic in some cases, and many of the units were strung together by a complex of "key beds," progressive lithologic redefinitions, and, in some cases, simple forcing of boundaries through otherwise *lithologically* indivisible sequences, purely on the basis of stratigraphic thickness.

The authors reexamined the *bulk lithostratigraphy* of the Upper Devonian and Mississippian in this area, and recognized *five* major lithosomes (three-dimensional rock masses) above the Devonian black shales and below the Pennsylvanian Pottsville Formation (Figure 1), which are both persistent lithostratigraphic units. These lithosomes include:

1. Devonian-Mississippian marine sequence
2. Catskill Formation
3. Devonian-Mississippian nonmarine sequence
4. Burgoon Sandstone
5. Mauch Chunk Formation (including Loyalhanna carbonates)

Three of the units, Catskill, Burgoon, and Mauch Chunk, have been specifically recognized and mapped in the past. The "Devonian-Mississippian marine sequence" has never been handled as a single entity, but has been variously presented over the years as a collection of local units. The "Devonian-Mississippian nonmarine sequence" has been separated, in effect, by exclusion from the underlying red Catskill and the overlying Bur-

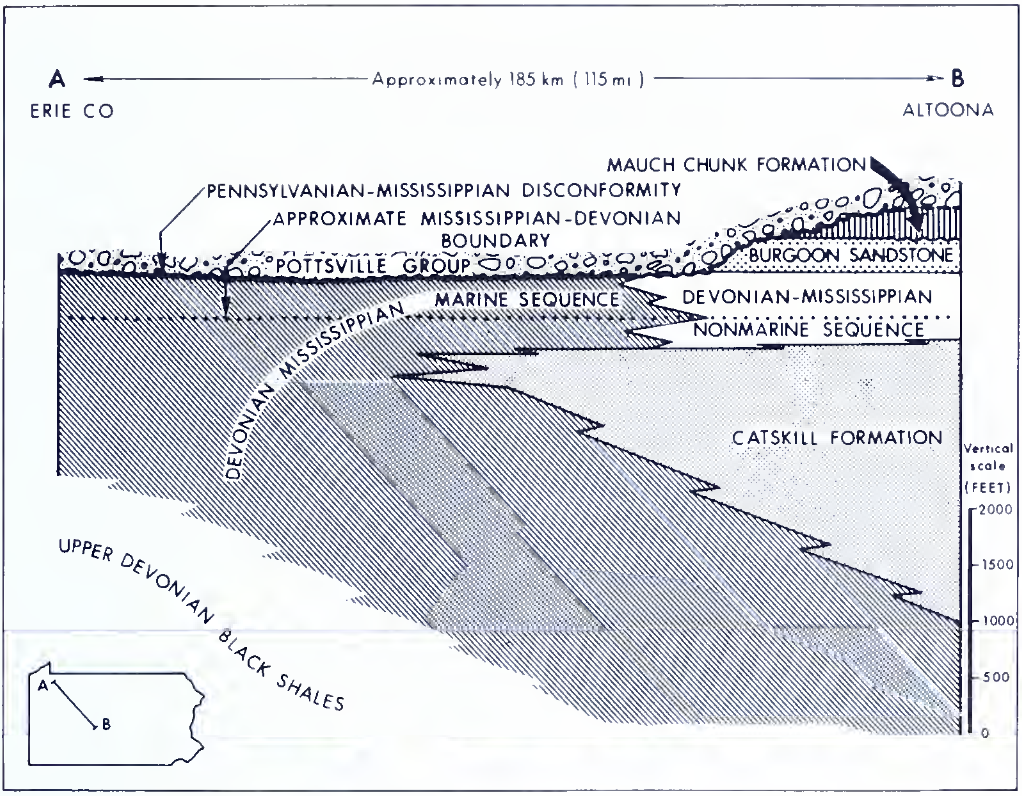

Figure 1. Major Mississippian and Upper Devonian lithosomes of north-central and western Pennsylvania.

goon. Internally, the unit constitutes a transition between the Catskill and Burgoon. A variety of names have been applied to parts of the "non-marine" sequence (number 3 above), and it is this lithostratigraphic unit that is formally named and defined in this report.

Nomenclatural History

In his first annual report to the Pennsylvania Legislature in 1836, Henry D. Rogers outlined a stratigraphic sequence for the Valley and Ridge province that lacked formal stratigraphic terminology in the modern sense, but contained the essential broad subdivisions that are still in use today. In describing the rocks overlying the uppermost red beds (today's "Catskill") of his "Appalachian system," Rogers cited (1836, p. 15) the presence of "peculiar vegetable fossils" and associated traces of coal as evidence of passage into the subordinate portion of the "great carboniferous system." He further described (1836, p. 15) the strata at the base of the Carboniferous as "a group of massive beds of coarse grey sandstone and conglomerate; the sandstones prevailing most in the lower portion; while towards the top fully

developed conglomerates of pure white and partially transparent quartz abound." Rogers named this sequence "the lower *Carboniferous Sandstone*" (1836, p. 16), and defined the upper boundary by the appearance of brown to "florid red" shale (today's "Mauch Chunk"). Overlying this red shale, and described in some detail by Rogers, are "the *Coal Measures.*" Thus, by the year 1836, the lithologic entity bounded above and below by red beds, and called lower Carboniferous Sandstone, was recognized as a widely mappable rock-stratigraphic unit in Pennsylvania.

With the issuance of his Second Annual Report, Rogers expanded on the stratigraphic sequence east of the Susquehanna River, and numbered the units from I to XIII. In describing his Formation No. X (lower Carboniferous Sandstone), he stated (1838, p. 62): "We ascend from Formation No. IX through a series of alternating strata, usually several hundred feet in thickness, comprising red shale and red argillaceous sandstone allied to that formation, and interposed grey sandstones and red and grey conglomerates connected with the heavy overlying deposits of Formation No. X . . . ." It is important here to point out that, very early in dealing with these particular strata, Rogers recognized that there was an interbedding of Formations IX and X, and that a *transition* between the two units exists. This is brought to the reader's notice here to point out that the contact between what has been called "Catskill" and "Pocono" was never conceived as a simple contact, and that the transition between the two units has caused difficulty in defining these units in Pennsylvania for almost a century and a half. Of additional importance is Rogers' heading in the 1838 report describing Formation No. X as the "SANDSTONES AND CONGLOMERATES OF THE SECOND MOUNTAIN AND THE SOUTH-EASTERN SUMMIT OF THE ALLEGHENY." He described the areal extent of Formation No. X (1838, p. 63-64), and mentioned that "it caps the Big Creek mountain, east of the Lehigh at Mauch Chunk [Jim Thorpe] . . . ." The geographical distribution that he described gives a fairly good idea of the stratigraphic interval he meant to include in Formation No. X. Rogers especially points out the Lehigh River and Susquehanna River stratigraphic sections for their excellent exposures.

In his Fourth Annual Report, Rogers went into some preliminary detail on the strata exposed in Lycoming, Clinton, and Tioga Counties. He said (1840, p. 149): "The Allegheny mountain, pursuing a nearly east and west direction through Lycoming county, consists, at its southern base, of the slaty rocks of F. VIII., overlaid by the red shales and sandstones of F. IX [Formation No. IX, Catskill]. Denuding floods, acting upon these relatively soft materials, have imparted a gently rounded and undulating contour to the surface. Immediately upon them rests the sandstone formation, F. X. of our series, which, by its greater hardness has presented a great barrier to the waters, imparting bolder features and steeper slopes." Farther on, Rogers stated (1840, p. 153): "The rocks along the Susquehanna river, are the argillaceous sandstones forming the thick bands at the alternation of F. IX. and

F. X. dipping at a considerable angle to the north-west." Again, in this part of Pennsylvania, Rogers recognized a *transition* between what was later to be called "Catskill" and "Pocono."

In the Fifth Annual Report, Rogers described at some length the occurrence of coal-bearing strata in the region northwest of the Allegheny Front. He frequently referred to the position of massive conglomeratic outcrops of F. XII (Pottsville). This unit is used persistently in his discussion as an easily recognizable point of reference or key bed in the vertical sequence. In describing the section near Caledonia (1841, p. 60), Rogers stated: "In the grey slaty sandstones of F. X., there occurs a bed of indifferent sandy limestone, about 4 feet thick. This contains many fossil shells and other marine remains, including those of one or two species of fish." In that statement is contained the first clear indication that Rogers would allow considerable lateral change within his stratigraphic sequence, and would extend his Roman-numbered system as far as possible, so long as the general framework appeared sound. On the same page (Rogers, 1841, p. 60), he described his Formation XI (Mauch Chunk) as having thinned out. He apparently wished to carry his stratigraphic framework as far as possible, and he relied heavily on the persistence of Formation XII (Pottsville) as a key horizon in central Pennsylvania. He seemed reluctant to complicate the nomenclature, as long as some of the basic stratigraphic components persisted. There was wisdom in Rogers' early work, and an admirable simplicity. He wished to erect a widely applicable rock-stratigraphic framework, and did not, in these early annual reports, seem to be overly concerned about elements of geologic time or chronostratigraphy. He understood the principle of superposition of strata, and applied that principle well with what information was available. The difficulties brought about by later definition of time-stratigraphic units did not confound his efforts.

When Rogers' final report on the First Geological Survey was published in 1858, he had formalized his stratigraphic terminology, substituting names of the diurnal hours for the twelve Roman-numbered units. Thus his Formation IX became the "Ponent," Formation X became the "Vespertine," Formation XI became the "Umbral," and Formation XII became the "Seral." Rogers' (1858, v. 1, p. 108) basic description of the Vespertine Conglomerate and Sandstone is as follows:

> White, grey, and yellowish sandstone, alternating with coarse silicious conglomerates, and dark-blue and olive-coloured slates. It frequently contains beds of black carbonaceous slate, with one or more thin seams of coal. The only organic remains are fragments of coal plants; some of these are specifically, and even generally, different from those of the Seral coal series. It has its greatest thickness near the Susquehanna, where it measures 2660 feet.

As in the Second Annual Report, Rogers referred to the maximum thickness exposed along the Susquehanna River (Second Mountain) and alluded to its excellent exposure.

In detailing the distribution of the Vespertine over the whole state, Rogers (1858, v. 1, p. 142-144) listed a variety of lithologies somewhat different than the basic description above, and he described the occurrence of fossils, naming in particular *Skolithos,* or a vertical wormlike form. Rogers described (1858, v. 1, p. 301) the Vespertine in the northeastern district of the state as "a succession of coarse silicious conglomerates, grey, white, and yellowish grits, and dark blue and olive-coloured shales, with an occasional bed of black carbonaceous slate." He explained that it exceeded 2,000 feet at the Susquehanna and measured about 1,300 feet near Mauch Chunk (Jim Thorpe). In discussing the bituminous coal fields, Rogers (1858, v. 2, p. 467-468) said that the finer Vespertine sandstone bordered the coal fields toward the southeast, along the length of the Allegheny escarpment. He further said that it skirted the coal fields on the northwest and extended into Ohio. He described the overlying Umbral red shales and pointed out the thinning and ultimate disappearance of that unit to the north. He said a similar disappearance of the underlying Ponent rocks rendered distinction of the Vespertine and the underlying "Vergent" (Formation VIII, in part) quite difficult. Despite these difficulties, Rogers proclaimed that the Vespertine rocks occurred "the whole distance to the Ohio River, and even into Kentucky."

Although Rogers violated no existing rules of stratigraphic practice, we can easily see the difficulties he encountered in carrying stratigraphic names as far as he did. He lost the bounding red beds of the Ponent (Catskill) and the Umbral (Mauch Chunk), and the Vespertine became finer and full of marine fossils, to the point of becoming indistinguishable from the underlying Vergent (later to be termed "Chemung").

The first published usage of the term "Pocono" was in J. P. Lesley's appendix description of the Boyd's Hill gas well at Pittsburgh in Report L of the Second Pennsylvania Survey on coke manufacture (Platt, 1876). Lesley described the basic units penetrated by the well, and referred to the "Pocono" as being equivalent to the *Vespertine* or "Mountain sandstone." Sevon (1969a, p. 54-62) presented a more thorough review of the origin of the name "Pocono" and drew attention to some discrepancies in dates of publications at that time. In 1877, the Platt brothers outlined what was then becoming common nomenclatural usage among geologists of the Second Survey. They stated (Platt and Platt, 1877, p. xxvi):

> If No. IX be properly called the Catskill Formation because it forms the mass of mountains between the Hudson river and the Delaware, it is perfectly proper that the Gray Sandstone Formation, No. X, next above it, should be called the Pocono Formation, for it forms the mass of the great mountain plateau between the Delaware and Lehigh rivers. And both these great formations attain their greatest development in the mountains thus named.

Parenthetically, a mistake was made here in the assumption that the "Gray Sandstone Formation, No. X" formed the great mass of the plateau from the Delaware to the Lehigh. It was not until 1960, when the fourth state

geologic map was issued, that the limits of Vespertine (Pocono) as originally conceived by Rogers were correctly eliminated from the Pocono Plateau.

In 1881, I. C. White recognized "transition layers, Sub-Pocono" in his report on the geology of Susquehanna and Wayne Counties (White, 1881, p. 58-60). Because this 375-foot- (115-m-) thick transitional sequence of "gray, current-bedded" sandstones and some reddish sandy shales did not appear easily separable to White, he chose to include it in the Catskill; he did not attempt to map a transition. He stated (White, 1881, p. 60): "The question of the propriety of including or excluding the upper transition beds in this estimate [Catskill Formation thickness] is left open; but there is certainly no such strong and decided break in the whole series of 2740′ from the base of the Pottsville conglomerate to the base of this Catskill series, as occurs at the base of the Pottsville."

In describing the geology of the Susquehanna River region, White (1883, p. 49-50) made concrete reference to a "Pocono-Catskill group," and stated that his study of this stratigraphic interval since the report of 1881 had confirmed his original opinion that it did constitute an "intermediate or *transition group.*" White (1883, p. 49-50) gave an excellent description of the transition:

> The group as a whole is composed largely of green and greenish-gray sandstones, interstratified with which are often found thin beds of *red shale,* and a considerable bed of the latter often occurs at the top of the group.
>
> When the rocks of this group become massive they take on a *Pocono aspect,* becoming coarse, gray, and even pebbly, while the *red shales* almost completely disappear from them. On the other hand, when the same beds become shaly or less massive the sandstones assume the peculiar greenish-gray characteristic of the *Catskill rocks,* while the *red beds* increase in thickness and number. The geologist unacquainted with their changing type would at one time place them unhesitatingly in the *Pocono,* and at another would feel sure that they belonged in the *Catskill* series.

In his description of the formations in the Gaines oil field (Potter and Tioga Counties), Fuller (1902, p. 611) described the Catskill Formation as characterized by gray and greenish sandstones mixed with persistent red beds. He was uncertain as to the application of the name Pocono. The sequence above the persistent red beds was described as dominantly greenish gray sandstone; the upper 150 to 250 feet (46 to 76 m) was described as being more buff or gray. In 1902 Fuller did not decide whether "Pocono" should be assigned to the total sequence above the persistent red beds or only to the thinner gray to buff sandstones beneath the Pottsville. A red bed ranging from 0 to perhaps 60 feet (0 to 18 m) was recognized above the rocks assigned to the Pocono, and below the Pottsville. This red bed was mistakenly assumed to be the Mauch Chunk Formation. In his discussion of the upper limits of the Catskill, Fuller displayed a chronostratigraphic approach (1902, p. 611): "In the absence of paleontologic evidence it is impossible to determine whether the transition from the Catskill to the Pocono should be considered as occurring at the upper limit of these persistent red beds or at some higher horizon in the series."

In his summation of Lower Carboniferous stratigraphy of the Appalachian basin, Stevenson (1903, p. 38 ff.) applied the term "Pocono" widely, extending it from Pennsylvania through Ohio and the Virginias to Kentucky, Tennessee, and Alabama. He used "Pocono" more as an interval, or a "great mass" as he put it, and carefully elaborated all the internal changes of lithology. His thinking was chronostratigraphic and he discussed faunal relationships in general.

In 1903, Glenn introduced two new stratigraphic names in southwestern New York for the interval between the Cattaraugus Formation (western continuation of the Catskill Formation) and the Olean Conglomerate (basal Pottsville Group). Glenn applied the term "Oswayo" to olive-green to rusty-colored sandy shales containing marine invertebrate fossils and overlying the uppermost red bed of the Cattaraugus (Glenn, 1903, p. 978-980). Above the Oswayo Formation, a thin interval of conglomerates interbedded with shales quite similar to the Oswayo was termed "Knapp Formation" (Glenn, 1903, p. 980). The Knapp was considered equivalent to the Shenango Formation conglomerate and shale of Pennsylvania and Ohio ("sub-Olean" conglomerate of Pennsylvania Second Survey workers). The Knapp was characterized in part by the discoidal shape of conglomerate pebbles, and in part by the presence of marine invertebrate fossils. Hard gray sandstone beds also characterized the Knapp.

In the same year (1903), Fuller used the name "Oswayo" for the thick sequence of green and gray sandstones overlying the persistent red beds of the Cattaraugus Formation both in the Gaines quadrangle (Fuller and Alden, 1903a, p. 2), and in the Elkland and Tioga quadrangles (Fuller and Alden, 1903b, p. 2). Fuller was in contact with Glenn, or was at least familiar with the name that Glenn had proposed for the supra-Cattaraugus succession, and he extended usage of "Oswayo" approximately 65 miles (105 km) from the type section in New York. Fuller chose not to utilize the term "Knapp," although he did recognize an interval occupying the upper 100 feet (30 m) of the Oswayo Formation that was lighter gray or buff sandstone, in contrast to the greenish sandstone below. In discussing terminology, Fuller chose not to utilize "Catskill" or "Pocono," and did not elaborate on his reasons, saying simply that distinctions attributable to those formations did not hold in the Gaines or Elkland-Tioga areas.

In 1913, Barrell summarized the state of knowledge of the Late Devonian delta deposited in the Appalachian geosyncline. In discussing the Pocono, he said (Barrell, 1913, p. 449): "The Mississippian period was opened by the development in the Appalachian geosyncline of a great sandstone formation, the Pocono sandstone. In character it is distinct from the preceding Catskill, though grading into it through a thick transition series." Barrell equated the base of the Pocono with the beginning of Mississippian time, and recognized a Catskill-Pocono transition. Further on, Barrell applied the name "Pocono" to "marine phases" in western Pennsylvania,

and said that the Oswayo was lithologically equivalent to the Pocono, but had a marine fauna (Barrell, 1913, p. 449-450). Thus, by 1913, usage of "Pocono" in a time-stratigraphic sense was indeed widespread.

Chadwick first articulated the need for separation of lithostratigraphic and chronostratigraphic thinking in dealing with the Late Devonian and Mississippian strata of northern Pennsylvania (Chadwick, 1933a, p. 177; 1933b, p. 91 ff.). Although disagreement over age determinations arose (White, 1934, p. 265 ff.; Chadwick, 1935, p. 133 ff.), Chadwick clearly outlined the change in facies of both "Catskill" and "Pocono" in an east-west direction across Pennsylvania. He also described the unconformity beneath the Pottsville conglomerates, and explained the northward physical loss and increasing age of strata beneath the unconformity (Chadwick, 1935, p. 135).

At about the same time, K. E. Caster completed his monumental work on the stratigraphy of northwestern Pennsylvania (Caster, 1934). Caster's thinking was similar to Chadwick's; one of his main purposes was to distinguish rock units from time-rock units. He formulated the concepts of magnafacies and parvafacies (Figure 2), in which magnafacies are "complete lithic units," and parvafacies are units bounded by time lines as well as by lithologic definition (Caster, 1934, p. 20-21). In applying his facies concepts to the Upper Devonian and Mississippian of northern Pennsylvania, Caster recognized seven magnafacies (Figure 3). The easternmost magnafacies is termed "Pocono," and includes coarse gray sandstone and some conglomerate. Moving west, a subjacent lithic unit, made up of finer grained, micaceous sandstone weathering brown, is called the "Tioga" magnafacies. Caster (1934, p. 23) stated that the Oswayo Formation of Fuller is a parvafacies of the Tioga Magnafacies. West of, and subjacent to, the "Tioga" is the Catskill Magnafacies comprising red and green sand-

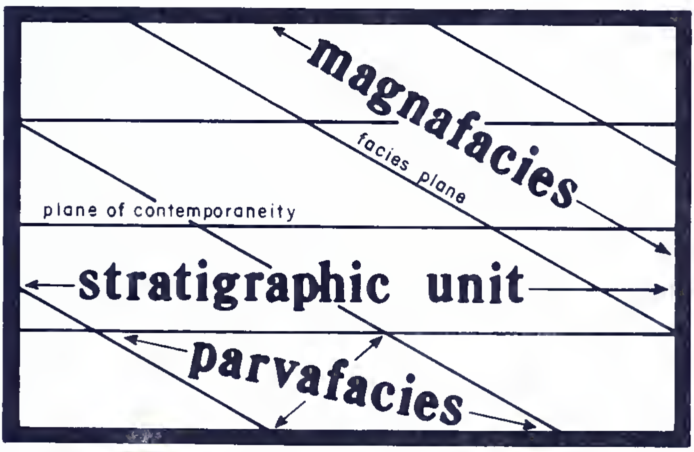

Figure 2. Facies components of Caster (1934). (Reproduced (in redrafted form) by permission of the Paleontological Research Institution, Ithaca, New York.)

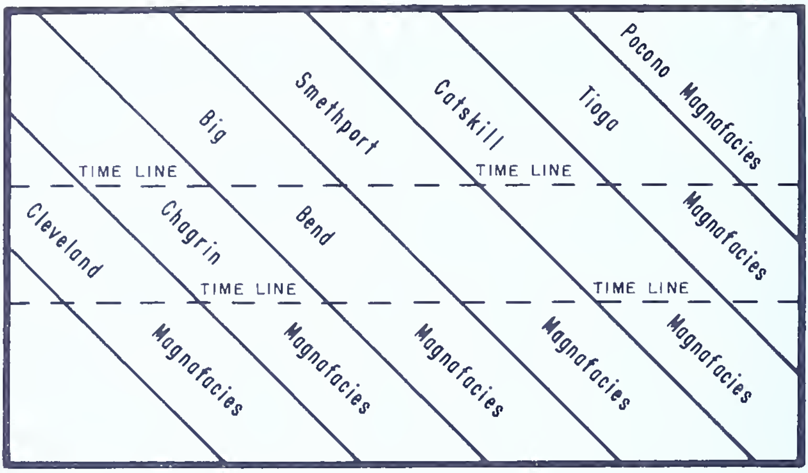

Figure 3. Seven magnafacies occurring across northern Pennsylvania as conceived by Caster (1934). (Reproduced slightly modified by permission of the Paleontological Research Institution, Ithaca, New York.)

stone and shale. Four other magnafacies are defined west of, and subjacent to, the Catskill. What Caster recognized as the "Tioga Magnafacies" is essentially the same lithostratigraphic unit that is being named and formally established in this report. Unfortunately, subsequent workers never attempted to test the mappability of Caster's "Tioga Magnafacies."

Willard (1936, p. 599-605) took issue with Chadwick's interpretation of the stratigraphic framework, refusing to accept significant eastward thickening of Catskill units in Pennsylvania. He clearly equated the Mississippian-Devonian time boundary with the base of the Pocono Formation. He said (Willard, 1936, p. 604): "The base of the Pocono appears to be not far from isochronous throughout." Although Willard recognized lithologic entities, the thrust of his thinking was manifestly time-stratigraphic.[1] He believed in a widespread Mississippian-Devonian unconformity, and dismissed a Catskill-to-Pocono transition. Willard did not recognize the Burgoon Sandstone as the total lithologic equivalent of the Pocono Formation, but considered it simply an upper member of the Pocono. This is in contrast to the concept adhered to here that the Burgoon is the lithostratigraphic equivalent of the Pocono of the Anthracite region. The equivalency of Burgoon and Pocono was elaborated by Glaeser (1973, p. 166), and more recently by Berg (1979, p. 3).

Willard subdued his opposition to the reality of a transition, but continued to link the Mississippian-Devonian time boundary with a Catskill-

[1]This is understandable to some degree, because the base of what was called "Pocono" appears to be almost isochronic in north-central and northwestern Pennsylvania, but not in eastern Pennsylvania.

Pocono lithologic break. In discussing the upper limits of the Catskill Formation, he said (Willard and others, 1939, p. 260):

> The top is drawn simply where the red or green Catskill sandstones and shales yield place to the gray, usually conglomeratic Pocono. Much has been said, particularly by members of the Second Pennsylvania Geological Survey, on the subject of "transition beds" between the Catskill and Pocono. In a sense they were quite right; for among the non-red units of the Catskill, particularly those developed in the northeastern quadrant of the State, some beds so closely resemble the Pocono that confusion has been common. As such, they no doubt adumbrate Pocono conditions, but each unit may be shown to pass into marine strata with Devonian fossils. In areas where the non-red Catskill is not so well understood, this separation is difficult, and it must be frankly admitted that the line cannot always be sharply drawn. While it is established upon stratigraphic and paleobotanic evidence that the bulk of the Pocono from beyond the southern boundary of the State east at least to Mauch Chunk is of Mississippian age, there is still a possibility of a doubt as to the precise age of the lowest part of what many call Pocono. I have suggested that there is a confusion here of true Pocono with the somewhat similar "Oswayo" on the Allegheny Front. Nevertheless, for all practical purposes the top of the Catskill can usually be drawn with close approximation.

Willard correlated the Oswayo Formation with the "Elk Mountain" unit of White (1881, p. 64), but the authors believe this to be a miscorrelation, and consider the Oswayo as the marine lateral equivalent of the lower part of White's "transition layers, sub-Pocono" (White, 1881, p. 58). The Elk Mountain strata are considered part of the Catskill Formation (Glaeser, 1969). Willard continued to speak of an Elk Mountain unit as being the continental equivalent of the marine Oswayo Formation of northwestern Pennsylvania (Willard, 1946, p.789). He first extended White's "Mount Pleasant red shale" (overlying the Elk Mountain) as the highest red-bed unit of the Catskill from Wayne County as far west as Bradford County (Willard and others, 1939, Figure 74). He later indicated that the Mount Pleasant extended out into the marine sequence, falling between the Oswayo Formation and the Knapp Formation in Potter County (Willard, 1946, p.789).

Willard's nomenclature and stratigraphic framework were perpetuated by Ebright and others in discussing the surface strata in the East Fork-Wharton gas field of Potter County. The "Pocono" was described as a "succession of alternating greenish gray sandstones, siltstones, and shales" (Ebright and others, 1949, p. 6). The "Pocono" was further described as including a red shale correlative with the Patton red shale at Redbank Creek (Jefferson County). The Oswayo Formation and overlying "Pocono" of Ebright and others are divided at what is believed to be the Mount Pleasant red shale. They did not recognize that the Burgoon Sandstone was not present in their study area of southwestern Potter County and eastern Cameron County. Pre-Pennsylvanian erosion removed any Burgoon from that area. Their "Pocono" and Oswayo are almost lithologically identical; they are separated on the basis of supposed identification of a key red shale unit (Mount Pleasant).

The usage of "Oswayo" was extended into Clinton County by Ebright and Ingham in their study of the Leidy gas field. They questionably identi-

fied the Burgoon Sandstone and used its basal conglomerate as a structure-contour horizon. The supposed identification of a red shale horizon as the key "Mount Pleasant" horizon was utilized to separate their sub-Burgoon "Pocono" and the underlying "Oswayo." It is interesting to note their difficulty in separating the "Pocono" and "Oswayo" on a strictly lithologic basis (Ebright and Ingham, 1951, p. 11): "Lithologically, it is difficult to distinguish between the fine- to medium-grained, gray sandstones and gray shales of the Oswayo and those of the Pocono. No coarse-grained or pebbly sandstones were observed in the Oswayo, but several small lenses of calcareous breccia or sandy limestone, similar to those of the Pocono are present." Had Ebright and Ingham divided the stratigraphic column at the Burgoon, and not tried to force through the "Mount Pleasant" horizon, which was considered, in effect, to be the Mississippian-Devonian boundary, they may have arrived at a more natural vertical succession that included a mappable Catskill-to-Burgoon transition.

In discussing the surface stratigraphy of the Hyner and Ferney anticlines in Centre, Clinton, and Lycoming Counties, Ebright used exactly the same approach as in the Leidy gas field. He recognized the Burgoon, applied "Pocono" to the sub-Burgoon Mississippian strata, applied "Oswayo" to the strata below what was thought to be the "Mount Pleasant" red shale, and glossed over the very close lithologic similarity between "Pocono" and "Oswayo" (Ebright, 1952, p. 6-9).

Bolger and Gouse (1953, p. 6) listed a number of fossil marine invertebrates occurring in the sub-Burgoon "Pocono" of the north-central part of the Driftwood 15-minute quadrangle. The invertebrates were found in two vertically separate zones. A problem was evident regarding the age of fossils. Bolger and Gouse stated (1953, p.7): "Most of the species in the two faunal zones are typically Devonian. The problem is posed as to whether the range of the fauna must be extended well into the Mississippian, whether there is post-Oswayo Devonian in the area, or whether the Oswayo extends much higher in the section than heretofore reported." The mixing of geologic-time thinking and rock-stratigraphic thinking is evident. Bolger and Gouse followed the earlier solution of Willard and identified a red bed at about the right interval as "Mount Pleasant" and applied "Pocono" and "Oswayo" terminology above and below.

This usage of Pocono and Oswayo held and was incorporated in the 1960 state geologic map (Gray and others, 1960), although it was noted that the "Pocono" included part of the "Oswayo" in Potter and Tioga Counties.

Trexler and others (1961, p. B84 ff.) recognized what they believed to be a widespread unconformity between the Catskill and the Pocono of the western part of the Anthracite region. They made this interpretation on the basis of regional loss of an upper gray member of the Catskill Formation which they believed to be the same as White's "Pocono-Catskill transition

group.'' Trexler and others (1962, p. C36) later named this unit the Spechty Kopf Member of the Catskill. They noted that, based on fossil plant evidence, much of the Spechty Kopf could be assigned an Early Mississippian age. They also suggested that the Spechty Kopf might be correlative with the marine Oswayo Formation. Hoskins (1970, p. 25) reexamined evidence for an angular unconformity separating the Catskill and Pocono Formations in the western and southern part of the Anthracite region, and discovered additional structural data that precluded the necessity of interpreting an unconformity. Missing stratigraphic section was explained by Hoskins as due to faulting.

Dyson (1967, p. 38) placed the Spechty Kopf Member in the Pocono Formation, and indicated that it constituted a transition between Catskill and Pocono. Sevon described a unique sequence of tilloid (polymictic diamictite) grading up through pebbly mudstone to laminite in the Spechty Kopf of northeastern Pennsylvania. He suggested that the unusual lithologies and vertical sequence were the result of subaqueous mudflows (Sevon, 1968, p. 54; 1969a, p. 25-29; 1969b, p. 218-221). Sevon further elaborated on Spechty Kopf lithic assemblages (Sevon, 1973, p. 218-219), and suggested glaciation in the source area. The Spechty Kopf was separated as an independent formation in 1974 (Epstein and others, 1974, p. 192); unconformities bound the formation both at the top and bottom. More recently, Sevon (1979) has discussed the widespread occurrence of the unusual Spechty Kopf lithologies and their origin.

In his mapping of the Cedar Run, Slate Run, and Waterville quadrangles (Potter, Tioga, Clinton, and Lycoming Counties), Colton traced an ''upper sandstone sequence'' and a ''lower sandstone sequence,'' straddling the presumed Mississippian-Devonian boundary (Colton, 1963a, 1968; Colton and Luft, 1965). The mapping of Colton in this region is the first since the early efforts of the Second Pennsylvania Survey in the 1800's. Colton (1963b, p. 124) suggested that new stratigraphic names might be justified in this region; names from other regions might also be valid. He left the question of nomenclature open until more mapping had been completed.

Colton's ''lower'' and ''upper'' sandstone sequences were treated as a single entity in compiling the 1980 geologic map of the state (Berg and others, 1980), and were mapped from Potter, Clinton, and northern Centre Counties eastward to Bradford and Wyoming Counties. This nonmarine clastic unit is not everywhere divisible as two sandstone sequences, the division hinging on location and identification of Colton's ''conglomerate at Cedar Run.''

In 1968, Woodrow named a new unit called the ''Sunfish Formation'' in Bradford County. Woodrow rejected the term ''Catskill'' on the grounds that it was a ''facies'' term and had no value as a formal stratigraphic name. It was also rejected because the basal contact, linked to the lowest red bed,

occupied lower and lower stratigraphic positions eastward across Bradford County. This seems to reflect an inclination to draw lithostratigraphic boundaries that are as nearly time-parallel as possible. ''Sunfish'' was defined (Woodrow, 1968, p. 25) as occupying a position interpreted by Woodrow as equivalent to the lower part of the Conneaut Group of western New York. The Conneaut Group, in fact, has no clear lithostratigraphic equivalent in Bradford County; strata having some genetic relation to the Conneaut occur below the Catskill Formation, within the Lock Haven Formation. Woodrow's ''Sunfish'' includes the upper part of the Catskill Formation, and the Catskill-to-Burgoon transition. Woodrow called the light-olive-gray sandstones near the top of Barclay Mountain ''Pocono.'' These strata are actually a continuation of the transition; the Burgoon Sandstone is identifiable higher in the section on Barclay Mountain.

DEFINITION OF THE HUNTLEY MOUNTAIN FORMATION

The Huntley Mountain Formation is herein defined as the clastic sequence between the Catskill Formation and the Burgoon Sandstone in north-central Pennsylvania. The Huntley Mountain is correlative with the Spechty Kopf Formation of the Anthracite region of northeastern Pennsylvania. It is the lateral equivalent of the Rockwell Formation of south-central Pennsylvania. The Huntley Mountain is correlative with the Oswayo-through-Shenango marine clastic succession of northwestern Pennsylvania.

The type section (Figure 4) of the Huntley Mountain Formation (Appendix) is at Huntley Mountain, near the village of Waterville, Lycoming County, Pennsylvania. This new formation name is applied to the combined ''lower sandstone sequence'' and ''upper sandstone sequence'' of Colton (1963b). Mapping of this new formation was completed for the 1:250,000 geologic map of the state (Berg and others, 1980); the boundaries as recognized by Colton were extended over a large part of north-central Pennsylvania.

Establishment of this formal rock-stratigraphic unit excludes application of the term ''Pocono'' to sub-Burgoon Mississippian rocks of north-central Pennsylvania. The Burgoon Sandstone is considered the rock-stratigraphic equivalent of the Pocono Formation of northeastern Pennsylvania, in keeping with the original meaning of Rogers' ''Formation X—Vespertine,'' and in keeping with the intent of Second Pennsylvania Survey workers' ''Pocono.'' Furthermore, establishment of this unit excludes the wide application of the term ''Oswayo'' to supra-Catskill Devonian rocks of north-central Pennsylvania. ''Oswayo'' is restricted to its original definition as given by Glenn (1903).

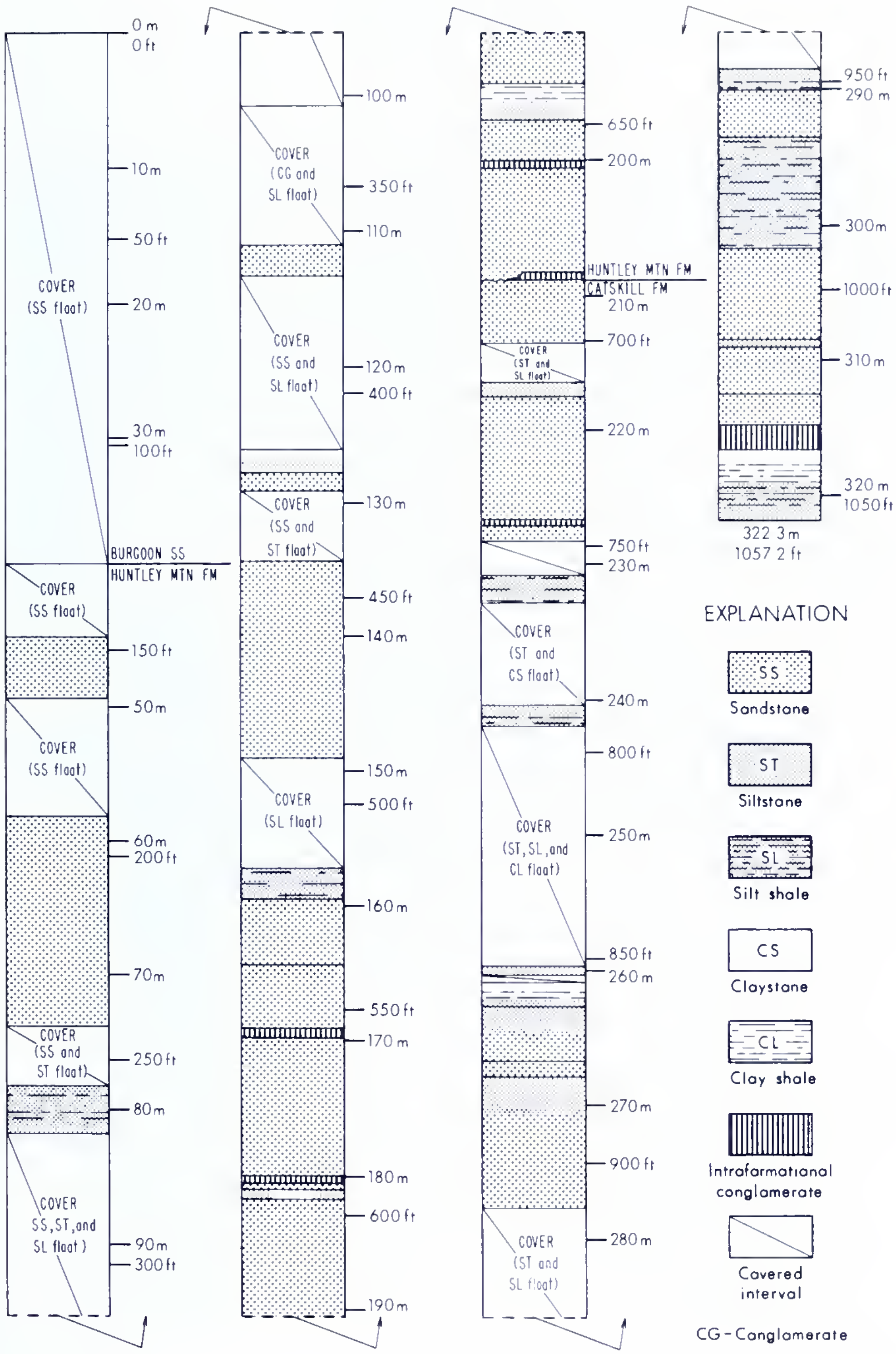

Figure 4. Columnar diagram of the type section of the Huntley Mountain Formation.

DESCRIPTION

LITHOLOGIES

The Huntley Mountain Formation comprises a sequence of dominantly greenish-gray to light-olive-gray sandstones, containing few grayish-red siltstone or clay shale beds. The sandstones in the lower part of the formation are similar to gray sandstones of the underlying Catskill Formation. Sandstones in the upper part of the Huntley Mountain are frequently yellowish gray or buff and appear superficially similar to the overlying Burgoon Sandstone. The transitional character of the Huntley Mountain is evident in the gross similarity of Huntley Mountain sandstones to both the Catskill sandstones and the Burgoon sandstones.

Sandstones

Megascopic Description

As a general rule, the Huntley Mountain sandstones are crossbedded or planar bedded, and are quite flaggy in weathering character (Figure 5).

Figure 5. Outcrop of flaggy sandstone in the Huntley Mountain Formation exposed along the south side of Case Glen at 41°46′39″N/76°50′41″W in the Troy quadrangle, approximately 4.7 km (2.9 mi) west of Troy, Pennsylvania (Bradford County). The scale is marked in feet.

Flagstone quarries have been developed in the Huntley Mountain (Figure 6). Steep slopes underlain by the Huntley Mountain are normally covered by very flaggy, greenish-gray sandstone float.

Figure 6. Flagstone quarry in the lower part of the Huntley Mountain Formation along the road ascending to Barclay, about 3 km (2 mi) southwest of Franklin Center, at 41°41′04″N/-76°36′05″W in the Powell quadrangle, Bradford County, Pennsylvania.

Sandstone in the upper part of the formation is light olive gray (5Y5/2)[1] to very light olive gray (5Y6/2). In places, buff or dusky yellow (5Y6/4) to moderate yellowish brown (10YR5/4) prevails. Sandstone in the lower part of the Huntley Mountain Formation is light olive gray (5Y5/2), greenish gray (5GY6/1), and medium greenish gray (5GY5/1).

Bedding thickness[2] of Huntley Mountain sandstones varies from very thin bedded to very thick bedded, and is most commonly medium bedded to

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[1] Color designations are from *Rock-Color Chart* (The Rock-Color Chart Committee, 1970).

[2] Stratification thickness terms are modified from Ingram (1954): thinly laminated, thinner than 0.3 cm (0.1 in.); thickly laminated, 0.3 to 1.0 cm (0.1 to 0.4 in.); very thin bedded, 1 to 3 cm (0.4 to 1.2 in.); thin bedded, 3 to 10 cm (1.2 to 4 in.); medium bedded, 10 to 20 cm (4 to 8 in.); thick bedded, 20 to 50 cm (8 to 20 in.); very thick bedded, 50 to 100 cm (20 to 40 in.); massive, greater than 100 cm (40 in.).

thin bedded. The sandstones are predominantly fine grained, but sometimes range up to medium grained. Locally, very fine grained beds occur.

The most striking primary sedimentary structure in Huntley Mountain sandstones is crossbedding. It is normally of trough style, occurring as sets that have curved lower bounding surfaces, and that have individual cross strata tangential to lower bounding surfaces (Figures 7 and 8). Lower

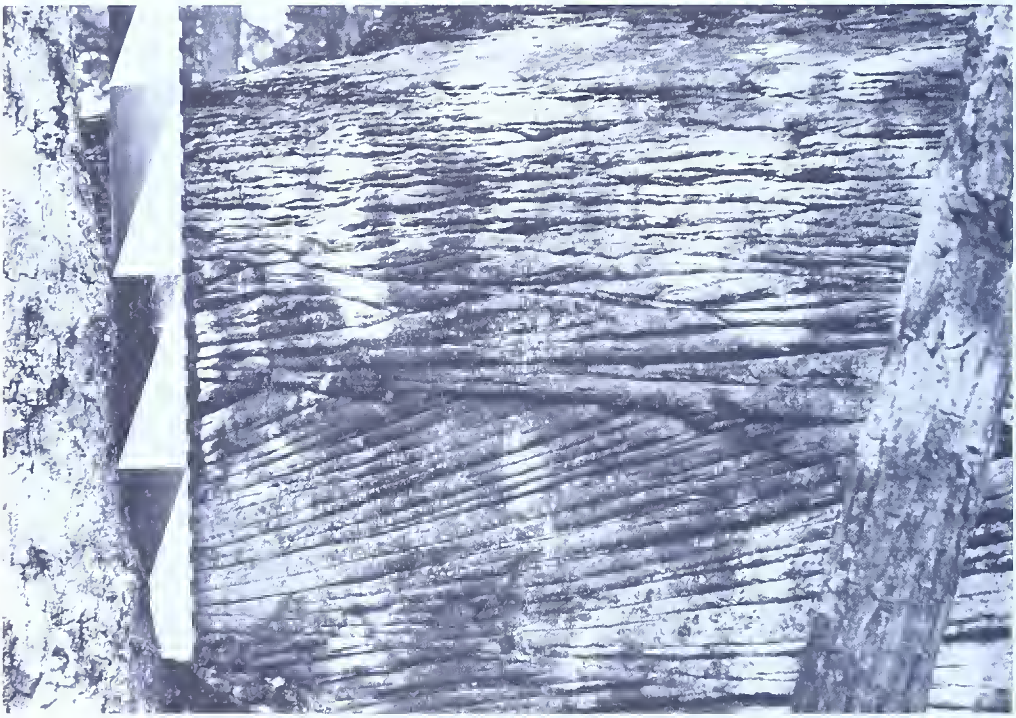

Figure 7. Outcrop of crossbedded sandstone in the lower part of the Huntley Mountain Formation at the type section (unit 31). Note the cross strata tangential to the lower bounding surface of the crossbed set. The scale is marked in feet.

bounding surfaces are generally curved, but are in many places at very low angles, resulting in very gently shaped trough crossbedding, contrasting with the higher angle, more strongly developed trough crossbedding observed in the Burgoon Sandstone (Figure 9). Sets of cross strata in the Huntley Mountain Formation are generally less than 0.5 m (1.6 ft) thick. Plane bedding is also very conspicuous in this formation (Figure 10), in many places overlying, and locally interbedded with, crossbedded sequences. Disintegration along plane bedding produces the very common flaggy breakup of the sandstone; the presence of plane bedding has resulted in the opening of many small flagstone quarries. Plane bedding and gentle trough crossbedding also occur in the underlying Catskill sandstones, but intervening red shales are more common in the Catskill.

Figure 8. Outcrop of trough crossbedded sandstone near the base of the Huntley Mountain Formation at the reference section along the west bank of Loyalsock Creek below the bridge at Barbours (41°23′36″N/76°48′03″W). Note the curved lower bounding surface of the crossbed set near the bottom of the ledge. The scale is marked in feet.

Other primary sedimentary structures in the Huntley Mountain sandstones include parting-plane lineation (Figure 11) and parting-step lineation (Figure 12). These lineation features on bedding surfaces are thought to be excellent paleocurrent direction indicators; the relationship between the lineations and internal rock fabric are discussed by McBride and Yeakel (1963, p. 780). Ripple bedding is another structure that is locally present in the finer grained sandstones of the Huntley Mountain. Asymmetrical current ripples are the most common form, although interference ripple marks occur in some places. At the horizon of the Cedar Run conglomerate, linguoid ripple marks have been observed (Figure 13).

Plant fossils, trace fossils, and rare invertebrate fossils have been observed in the sandstones, and these will be discussed under "Paleontology and Age."

Natural fragmentation of Huntley Mountain sandstones is generally flaggy or slabby, but some breakup is platy. In a few places, rubbly or blocky fragmentation occurs.

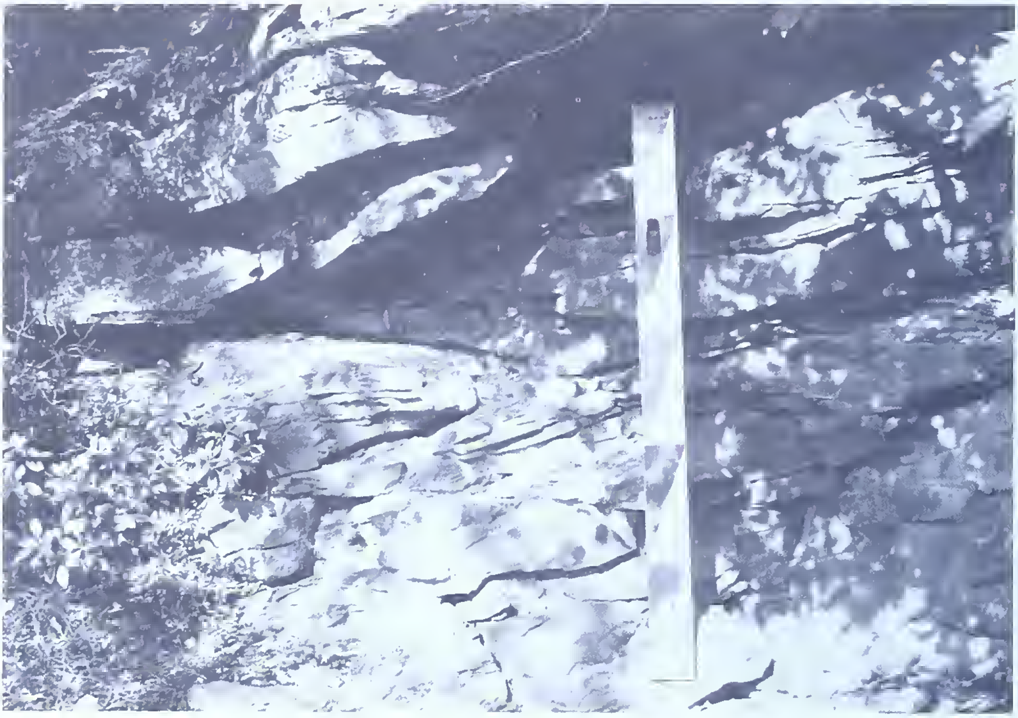

Figure 9. Outcrop of trough crossbeds in the Burgoon Sandstone at the type section of the Huntley Mountain Formation (supplemental section, unit 10). Note the curved lower bounding surface of the crossbed set left of the upper part of the scale. The scale is 5 feet (1.5 m) long.

Microscopic Description and Classification

Fifteen thin sections of sandstone sampled at the type section of the Huntley Mountain Formation were analyzed with a petrographic microscope and point counted to determine composition. Additionally, four Catskill Formation sandstone samples, eight Burgoon Sandstone samples, and three Cedar Run conglomerate samples were made into thin sections and analyzed.

The results of the thin-section analysis are shown in Figure 14. The classification scheme used herein is based on a combination of Folk (1968) and Folk and others (1970). In this classification, a *litharenite* is a sandstone in which the framework contains less than 75 percent quartz and metamorphic quartzite, and more than 25 percent detrital rock fragments and feldspars; the ratio of feldspars to rock fragments is less than 1:3. A *sublitharenite* is a sandstone in which the framework contains 75 to 95 percent quartz grains and metamorphic quartzite fragments, and 5 to 25 percent rock fragments and feldspars; the ratio of feldspars to rock fragments is less than 1:1. A *quartzarenite* is a sandstone in which the framework contains more than 95 percent quartz; the remaining 5 percent of the framework is any combina-

Figure 10. Planar bedding in Huntley Mountain Formation sandstone near the base of a fining-upward cycle in the flagstone quarry at 41°29′26″N/77°30′37″W, in the Slate Run quadrangle (Lycoming County). The scale is divided in inches and half feet.

tion of rock fragments or feldspars. Where it is possible to identify the rock fragments within the framework as metamorphic, rather than sedimentary or igneous, the *litharenites* and *sublitharenites* may be more specifically termed *phyllarenites* and *subphyllarenites*. The ratio of metamorphic rock fragments to sedimentary rock fragments must be greater than 1:1; the ratio of metamorphic rock fragments to igneous rock fragments must also be greater than 1:1. Figure 14 shows that the Huntley Mountain sandstones occur in both the sublitharenite and litharenite fields. On the basis of the four Catskill samples analyzed, it appears that the Huntley Mountain sandstones are somewhat more quartz-rich, and that Catskill sandstones may fall lower in general in the litharenite field. However, more sampling and analysis are needed. The Burgoon Sandstone analyses have an apparently narrower range of composition, and occur in the sublitharenite and quartzarenite fields. The three Cedar Run conglomerate samples all fall in the quartzarenite field.

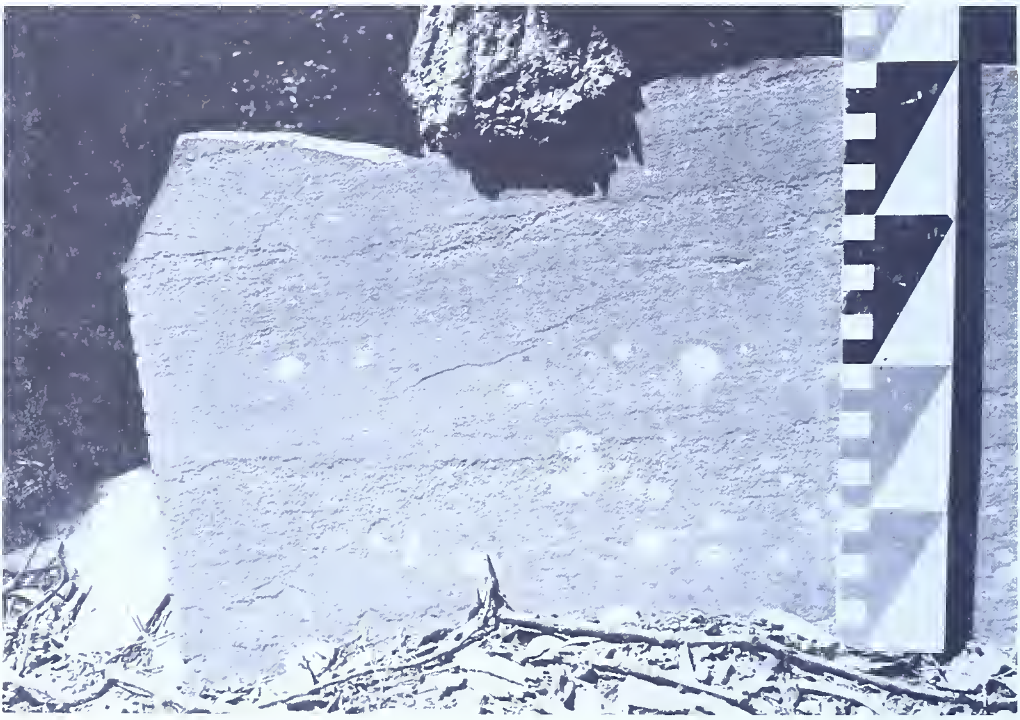

Figure 11. Flaggy sandstone from the Huntley Mountain Formation type section, unit 40. Note the parting-plane lineation across the lamination surface, near the middle of the slab. The scale is divided in inches and half feet.

Figure 12. Parting-step lineation (below coin) in flagstone at the Huntley Mountain Formation type section, unit 40. The scale is a quarter dollar.

Figure 13. Linguoid ripple marks in sandstone float associated with the Cedar Run conglomerate at the Huntley Mountain Formation type section, unit 49. The hammer gives the scale.

The percentage of quartz in the framework of the sandstones was compared to estimate the variability of that component. The average quartz content of Huntley Mountain sandstone samples analyzed is 76.4 percent, and the standard deviation is 7.42 percent. The average quartz content of Burgoon Sandstone samples analyzed is 88.3 percent, and the standard deviation is 5.39 percent. Catskill and Cedar Run samples were considered too few for comparison.

As was mentioned, Folk's classification scheme allows for subdivision of the litharenites, based on dominant rock fragment type in the framework. Because metamorphic rock fragments predominate in all the thin sections analyzed, the sandstones can be classified as subphyllarenites or phyllarenites. Even in the few quartzarenites analyzed, the rock fragments are metamorphic. A problem as yet unresolved, which affects this classification, is the presence of a component that is a composite of illite and chert (or microcrystalline or cryptocrystalline silica) and has variable amounts of chlorite. These masses or pockets (Figure 15A, B, C) have been counted as binder and not as framework, because distinct grain boundaries could not be seen. The masses appear to fill the spaces between framework grains. If these masses are in fact crushed or "squeezed" sedimentary or metamorphic rock fragments, and if they were counted as such, many of the points plotted in Figure 14 would fall lower into the litharenite field.

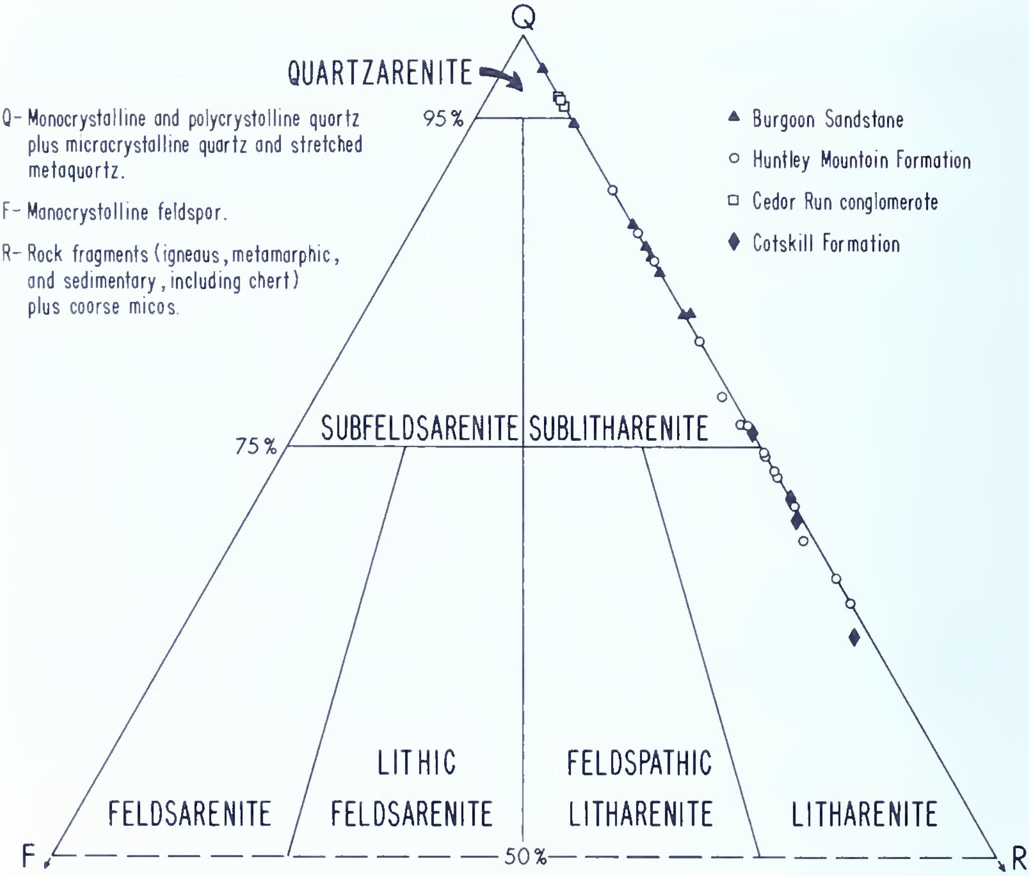

Figure 14. Triangular composition diagram showing the distribution of Huntley Mountain, Catskill, and Burgoon sandstones in the classification categories of Folk (1968).

Folk's classification (Folk, 1968) further includes application of a modifier to indicate textural maturity. An *immature* sandstone is one which contains more than 5 percent detrital clay matrix, and the framework sand grains are poorly sorted and angular. A *submature* sandstone is one which contains less than 5 percent detrital clay matrix, and the framework sand grains are poorly sorted and not well rounded. A *mature* sandstone is one which contains little or no detrital clay matrix, and the framework sand grains are well sorted, but not rounded. A *supermature* sandstone is one which contains no detrital clay matrix, and the framework sand grains are well sorted and well rounded. Because most of the Huntley Mountain samples contained more than 5 percent clay matrix, they fall into the "immature" category, and may be classified as *immature phyllarenite* or *immature subphyllarenite*. Four analyses showed less than 5 percent matrix, and subangular grains; these can be classified as *submature subphyllarenite*. The lower clay-matrix content appears above the conglomerate at Cedar Run. The Burgoon Sandstone shows variable textural maturity, and includes *im-*

mature, *submature*, and *mature subphyllarenite*, and one sample was analyzed as a *mature quartzarenite*. The Cedar Run conglomerate is a *submature* to *immature quartzarenite*. The Catskill Formation sandstones are *immature* to *submature phyllarenite* to *mature subphyllarenite*. The difficulty centering around interpretation of illite-chert composite masses also has an effect on interpretation of textural maturity. If these masses are counted as matrix, all the samples analyzed would clearly be *immature*. However, it could not be determined whether these masses were entirely detrital or entirely (or in part) authigenic. Because the illite seems intimately related to what appears to be chert cement, the masses were counted with cement and considered authigenic.

The predominant framework component in the Huntley Mountain Formation samples is quartz. The quartz occurs as single or semicomposite grains which are normally strained to a small degree, displaying slightly undulose extinction. Few grains display strong undulose extinction (Figure 15C). The quartz also occurs, to a lesser degree, as polycrystalline quartz (Figure 15D, E). Generally there is about six times as much monocrystalline to semicomposite quartz as polycrystalline quartz. Various inclusions occur in some quartz grains, including vermicular chlorite (Figure 15F, H, I), rutile (Figure 15J), platy microlites (Figure 15G), and vacuoles. In very few samples, microcrystalline quartz and stretched metaquartz (Figure 15H) occur as framework. The secondary framework component is metamorphic rock fragments (Figure 16A, B). The metamorphic fragments are mostly schist (sericite schist, chlorite schist). In some samples the schist fragments are crushed, and may be confused with illite-chert composite binder. Other minor framework components include siltstone fragments (Figure 16C), detrital chert (Figure 16A, E), detrital chlorite (Figure 16D), muscovite (Figure 16F) and biotite, and plagioclase (Figure 16G). In some samples, coarse detrital muscovite is very common, and composes up to 12 percent of the framework.

Other detrital accessory grains include leucoxene, zircon (Figure 16E), apatite, hematite, and limonite. These accessories rarely exceed one percent.

Framework components (and accessory minerals) in the Burgoon Sandstone and Catskill Formation sandstone are similar to the Huntley Mountain Formation sandstone, but vary in proportion, as indicated by the classification (Figure 14).

The binder (matrix or cement) in Huntley Mountain sandstones is very complex and presents many difficulties in determining detrital modes. The binder averages 27.4 percent of the total rock volume. Authigenic silica overgrowth on quartz (Figure 15J and 16F) is a major cement in the Huntley Mountain samples, ranging from 3.0 to 11.2 percent, and averaging 7.1 percent. The presence of concavo-convex, sutured, and long contacts between quartz grains (Figure 15C) indicates that there has been significant pressure solution, mobilization, and redeposition of silica in the sandstones. Besides

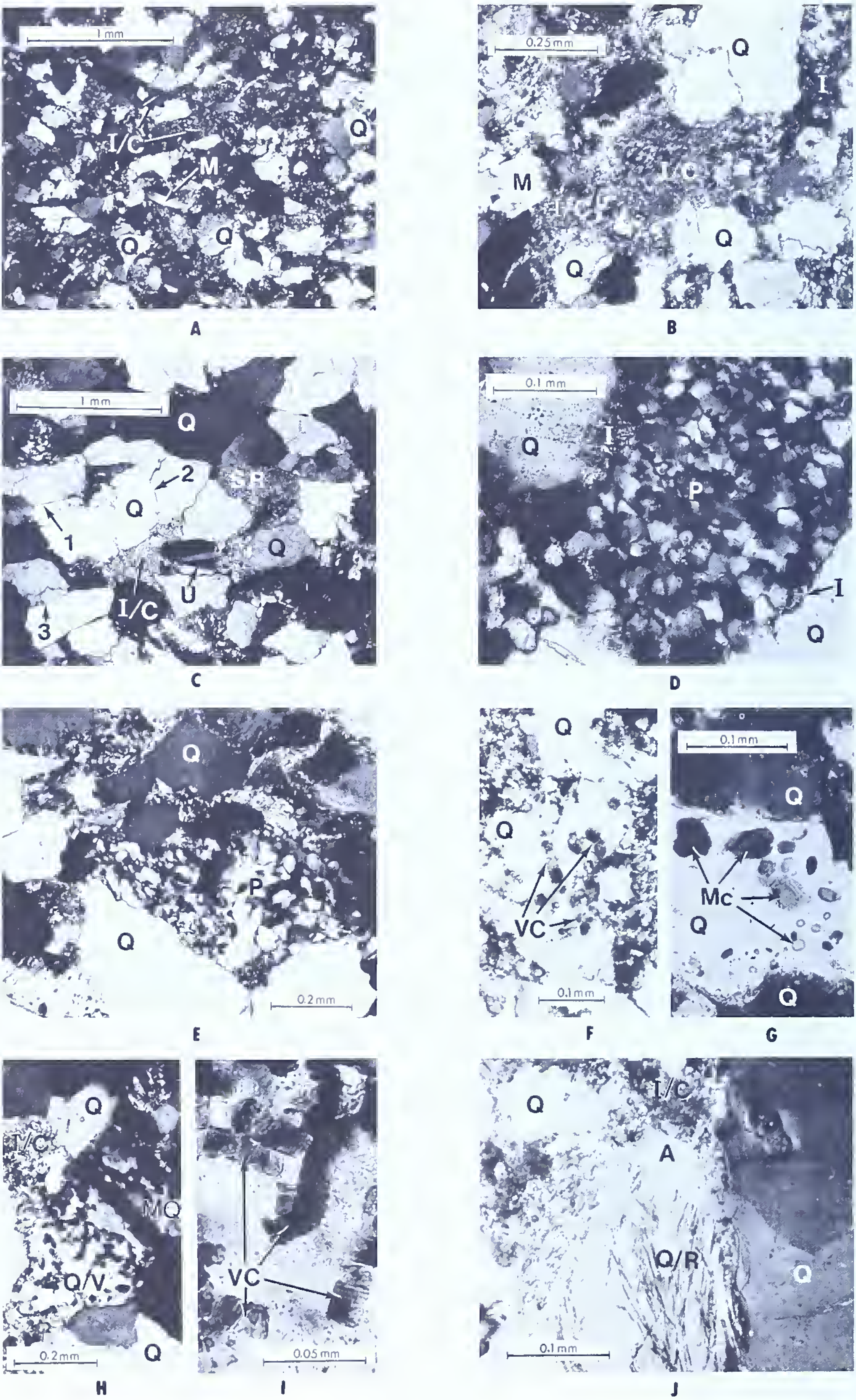
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Figure 15. Photomicrographs of thin sections of:

A. Huntley Mountain Formation sandstone (thin section no. WV–38), showing typical immature phyllarenite composition and texture. Note the quartz grains (Q), muscovite (M), and illite-chert composite binder (I/C). Crossed nicols.

B. Huntley Mountain Formation immature phyllarenite (thin section no. WV–38), showing the quartz framework (Q), a muscovite grain (M), the illite-chert composite binder (I/C), and the illite matrix (I). Crossed nicols.

C. Burgoon Sandstone (mature quartzarenite; thin section WVS–13e) showing the contrast between a siltstone rock fragment in the framework (SR) and the illite-chert composite binder (I/C) which is squeezed between framework grains. Note the quartz framework (Q), which includes one grain displaying well-developed undulatory extinction (U). Framework grain contacts are straight (1), concavo-convex (2), or sutured (3). Crossed nicols.

D. Huntley Mountain Formation sandstone (thin section no. WVS–7b) showing quartz (Q), polycrystalline quartz (P), and illite matrix (I). Crossed nicols.

E. Burgoon Sandstone (immature subphyllarenite; thin section no. WVS–13d) showing a framework of monocrystalline quartz (Q) and polycrystalline quartz (P). Crossed nicols.

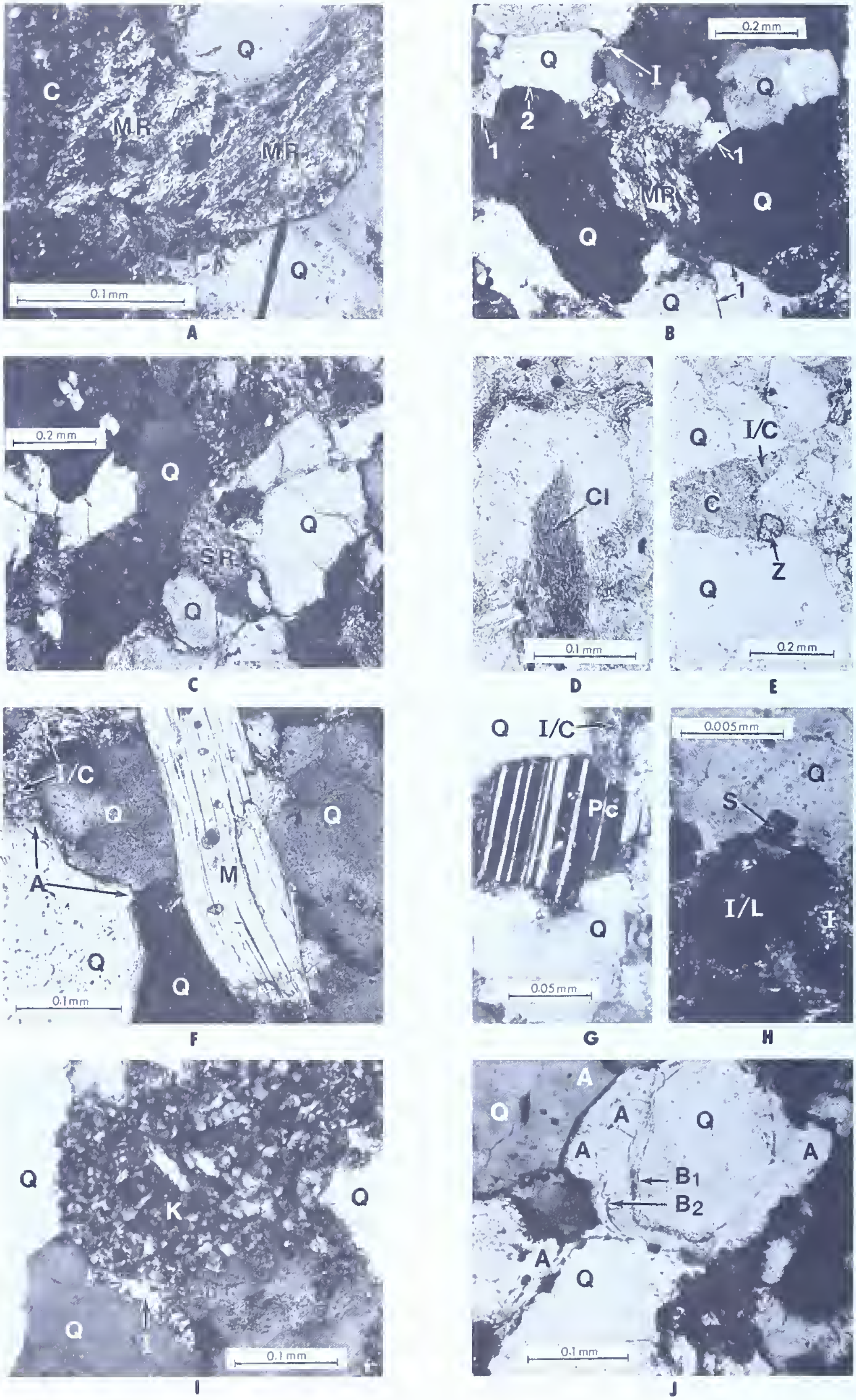
F. Huntley Mountain Formation immature subphyllarenite (thin section no. WV–36a) showing quartz grains (Q) and vermicular chlorite inclusions (VC). Crossed nicols.

G. Huntley Mountain Formation sandstone (thin section no. WV–38) showing quartz grains (Q) and platy microlite inclusions (Mc). Crossed nicols.

H. Burgoon Sandstone (thin section no. WVS–13d) showing quartz (Q), quartz containing vermicular chlorite inclusions (Q/V), stretched metaquartz (MQ), and illite-chert composite binder (I/C). Crossed nicols.

I. A closer view of the vermicular chlorite inclusion shown in Figure 15G. Photographed at higher magnification; crossed nicols.

J. Huntley Mountain Formation sandstone (thin section no. WV–62a) showing quartz grains (Q), quartz having rutile needle inclusions (Q/R), authigenic quartz overgrowth cement (A), and illite-chert composite binder (I/C). Crossed nicols.



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0.005 mm
Q
S
I/L
I
H
Q
K
Q
Q
0.1 mm
I
A
Q
A
A
Q
A
B1
B2
A
Q
0.1 mm
J

Figure 16. Photomicrographs of thin sections of:

A. Huntley Mountain Formation immature subphyllarenite (thin section no. WV–32) showing quartz grains (Q), metamorphic rock fragments (MR), and detrital chert (C). Crossed nicols.

B. Burgoon Sandstone (immature subphyllarenite; thin section no. WVS–13d) showing quartz grains (Q), a metamorphic rock fragment (MR), and the illite matrix (I). Note the straight grain contacts (1) and the concavo-convex grain contact (2). Crossed nicols.

C. Huntley Mountain Formation submature subphyllarenite (thin section no. WV–64) showing the quartz (Q) framework and a detrital siltstone rock fragment (SR). Crossed nicols.

D. Catskill Formation sandstone (thin section no. WV–26) showing detrital chlorite (Cl) at the position of maximum pleochroic color. Plane-polarized light.

E. Burgoon Sandstone (thin section no. WVS–13d) showing a zircon grain (Z), quartz grains (Q), detrital chert (C), and illite-chert composite binder (I/C). Plane-polarized light.

F. Huntley Mountain Formation submature subphyllarenite (thin section no. WVS–7a) showing a muscovite fragment (M), quartz grains (Q), authigenic quartz overgrowth cement (A), and illite-chert composite binder (I/C). Crossed nicols.

G. Huntley Mountain Formation immature subphyllarenite (thin section no. WV–47) showing a plagioclase grain (Pc), quartz grains (Q), and illite-chert composite binder (I/C). Crossed nicols.

H. Huntley Mountain Formation immature phyllarenite (thin section no. WVS–7d) showing quartz (Q), illite-limonite composite binder (I/L), illite matrix (I), and authigenic siderite (S) developed in quartz at the edge of the quartz-binder contact. Crossed nicols.

I. Huntley Mountain Formation immature subphyllarenite (thin section no. WV–62a) showing the kaolinite matrix (K), quartz grains (Q), and the illite matrix (I). Crossed nicols.

J. Conglomeratic sandstone at Cedar Run (thin section no. WV–58b) showing quartz grains (Q) and authigenic quartz overgrowth cement (A). Note the multiple quartz overgrowth history as indicated by successive relict grain boundaries (B_1, B_2). Crossed nicols.

silica cement, the remaining binder includes illite matrix (Figures 15B, D, and 16H, I), illite-limonite composite (Figure 16H), or illite-chert composite (Figures 15A, B, J, and 16F). Variable amounts of chlorite are bound up with the illite matrix and illite-chert composite. Small amounts of kaolinite in discrete pockets occur (Figure 16I), along with traces of pure chlorite, hematite, and siderite (Figure 16H). The illite-chert composite was counted as being authigenic, and averages 10.7 percent of the total rock volume in Huntley Mountain samples. In many samples, it is difficult to distinguish the illite-chert composite from crushed sericite schist fragments and crushed siltstone or claystone fragments.

Similar binding components were counted in the Burgoon Sandstone samples. Binder averages 23.9 percent of total rock volume. Authigenic silica overgrowth on quartz averages 9.2 percent, and illite-chert composite averages 7.6 percent.

Somewhat more diversity in binder composition is indicated by the four Catskill analyses. Binder averages 30.6 percent of total rock volume. Authigenic silica overgrowth on quartz averages 7.9 percent, and illite-chert composite averages 12.2 percent. In one thin section, hematite cement made up 14.4 percent of the total rock volume. A trace of calcite (about 0.5 percent) occurred in one thin section. No calcite was observed in any Huntley Mountain or Burgoon sections.

Binder in the Cedar Run conglomerate averages about 26.3 percent of total rock volume, and includes illite matrix (5.5 percent), kaolinite matrix (1.5 percent), authigenic silica overgrowth cement (Figure 16J) (10.5 percent), illite-chert composite cement (8.4 percent), and a trace of hematite cement.

In thin section, the Huntley Mountain Formation sandstones are fine grained (average grain diameter is 0.18 mm). The Catskill Formation sandstones are also fine grained (average grain diameter is 0.13 mm). The Burgoon Sandstone samples are medium grained (average grain diameter is 0.28 mm).

Red Beds

Approximately five percent of the Huntley Mountain Formation is what has been loosely termed "red beds." Included here are siltstones, silt shales, claystones, and clay shales that are grayish red (5R4/2 and 10R4/2) or brownish gray (5YR4/1). Because of their fine-grained nature and lack of resistance to erosion, there are very few exposures of these reddish units. They are for the most part thin, and generally do not exceed 2 m (7 ft) in thickness. Their presence is indicated by a change in slope to a gently or nearly flat configuration, in contrast to the steep slopes that are underlain by sandstone. Many of the red beds act as aquitards and produce perched water tables and lines of springs. Even where there is no outcrop, some

small float fragments of reddish units can be unearthed; many downed trees have red-bed fragments in their roots.

The red beds are most commonly located at the tops of fining-upward cycles, and may grade upward to gray, greenish-gray, or olive-gray shales (Figure 17). Fossil plant leaves and some very small trace fossils are found in the fissile red shales. Fossil plant rootlets and root systems are locally found in the red siltstones or claystones. Many of the red siltstones and silt shales are quite micaceous. Stacked fining-upward subsequences and ripple bedding are common primary sedimentary structures in the red beds. The red siltstones and claystones are nonfissile, are mostly thickly laminated to thin bedded, and break up to hackly or rubbly fragments. Some of the red claystones weather to a semiplastic condition. The red clay shales and silt shales are fissile to subfissile, thinly to thickly laminated, and chippy or flaky to hackly in natural fragmentation.

Figure 17. Fining-upward cycle in a flagstone quarry in the Huntley Mountain Formation at 41°29′26″N/77°30′37″W in the Slate Run quadrangle. A closer view of the basal sandstone is illustrated in Figure 10. Red beds in the upper part of the cycle (above the scale) grade vertically to thin, olive-colored claystone just below the basal sandstone of the succeeding cycle (near the upper third of the highwall). The scale is divided in feet.

Two of the red-bed units are thought to be very persistent, and have been referred to by formal names. The red shale directly below the Burgoon Sandstone has been called "Patton," and does indeed seem ubiquitous (Ebright, 1952, p. 8; Colton, 1968). The red shale within the lower part of the Huntley Mountain, approximately 30 m (100 ft) above the base, has been loosely referred to as the "Mount Pleasant" red shale (Willard, 1946, p. 789; Ebright, 1952, p. 8). Actual correlation of these red units with the Patton Shale of Campbell (1904) in Jefferson County or the Mount Pleasant Shale of White (1881, p. 59, 63) in Wayne County has not been accomplished, and is only speculation. The apparent ubiquity of the "Patton" just below the Burgoon may be due to the fact that natural exposures of the base of the Burgoon are best developed and most visible where an underlying red shale is present and has been eroded to undercut the overlying sandstone and produce a striking outcrop.

Minor Components

Intraformational Conglomerate

Conglomerates in which the clasts are apparently reworked fragments of partly lithified sandstone or shale, set in a poorly sorted, very sandy, calcareous matrix, are locally present at the bases of fining-upward cycles. Many of the reworked sedimentary clasts are quite angular. This feature, along with the concentration of calcite as a cement, has caused the conglomerate beds to be referred to as "calcareous breccias" by earlier workers. Clasts in some beds are subrounded. These intraformational conglomerates occur as discontinuous beds, and are generally less than 1 m (3 ft) in maximum thickness. Some conglomerate beds are noncalcareous. Scattered, rounded quartz pebbles occur, and fossil plant debris is not uncommon in intraformational conglomerates. These conglomerates are not unique to the Huntley Mountain Formation, and do occur in the underlying Catskill Formation. Calcareous intraformational conglomerates have never been observed in the Burgoon Sandstone, but some very thin, noncalcareous intraformational conglomerates do occur in the Burgoon.

The intraformational conglomerates are mottled shades of red, gray, and greenish gray. Some shale clasts are quite large, measuring up to almost 30 cm (12 in.) in length. Many conglomerate beds weather to various shades of brown, and generally form a recess below overlying sandstone beds (Figure 18). Because of leaching of carbonate, the surfaces of many weathered conglomerate beds are friable or powdery. Natural fragmentation of intraformational conglomerate is hackly or rubbly. Bedding is poorly defined.

Extraformational Conglomerate

Conglomerate beds in which the clasts have been derived from a source outside the formation in which they occur are referred to as "extraforma-

Figure 18. Intraformational conglomerate (unit 38 of type section), weathered to form a recess in an outcrop of Huntley Mountain Formation sandstone. The scale is 5 feet (1.5 m) long and rests at the position of the conglomerate.

tional" in contrast to "intraformational" wherein simple reworking accounts for the clasts. One principal extraformational conglomerate occurs in the Huntley Mountain Formation, and that has been called the conglomerate at Cedar Run by Colton (1963b, p. 120). In describing this key conglomerate bed, Colton (1963a) said it is a sparsely conglomeratic sandstone or lens-like conglomerate containing pebbles of milky and pinkish quartz, small numbers of pebbles of smoky quartz, gray chert, and jasper, and few pebbles of older rocks. This extraformational conglomerate crops out in

only a few places, but can be traced with confidence as float because of its distinctiveness for 800 square miles (2,100 km^2) (Colton, 1963b, p. 122).

The conglomerate at Cedar Run is about 110 m (360 ft) above the base of the Huntley Mountain Formation, and can be used successfully, as Colton has shown, to subdivide the sequence between Catskill and Burgoon. The conglomerate and conglomeratic sandstone is yellowish brown (10YR6/4), and has a wide array of grain sizes, ranging from fine to very coarse grained and pebble sized. Pebble varieties are as Colton has described (above). The pebbles are rounded to subrounded, and display low sphericity (Figure 19). Linguoid ripples (Figure 13) and ripple-drift struc-

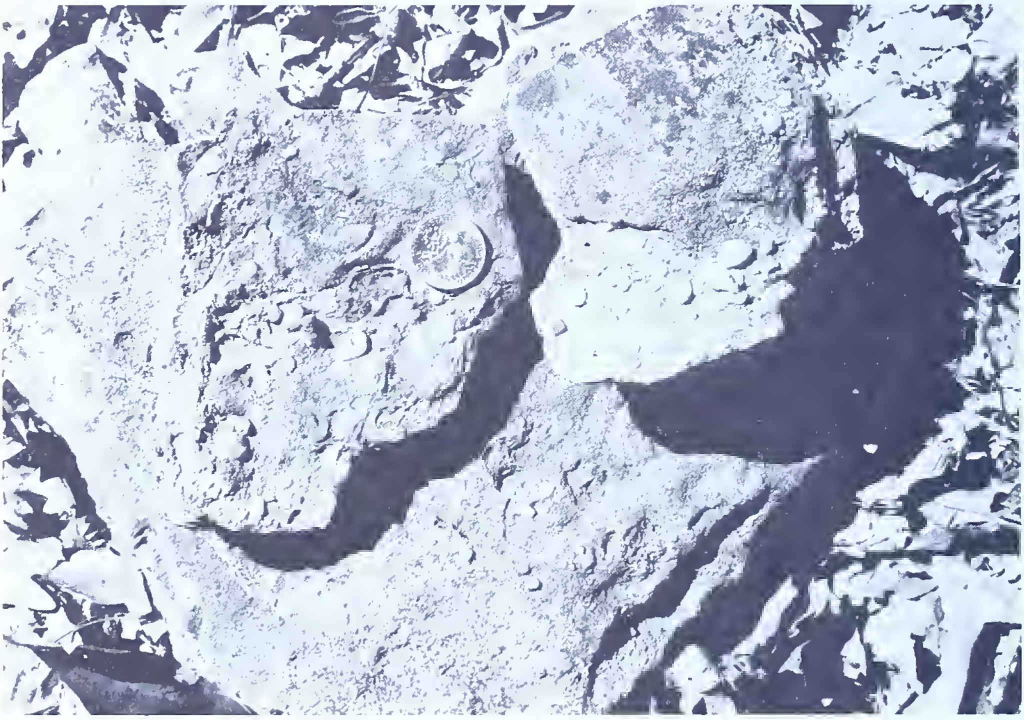

Figure 19. Extraformational conglomerate (conglomerate at Cedar Run of Colton, 1963b); unit 49 of the type section. Note the size and shape of the pebbles. A quarter dollar gives the scale.

ture appear in this unit. Rare fossil spiriferid brachiopods are found in the extraformational conglomerate, making this the only part of the Huntley Mountain that is unquestionably marine in origin. Some trace fossils (Figure 20), occurring as hypichnial ridges and burrow casts and identified as *Planolites* Nicholson, occur in the conglomeratic sandstone at Cedar Run. A *hypichnial* ridge is one in which the trace fossil (ridge) is (or was) in contact with the *lower* surface of the main casting medium, which, in this case, is sand that filled in a fossil trail depression. Natural fragmentation of the Cedar Run is slabby to rubbly. In thin section, the conglomeratic sandstone

Figure 20. Hypichnial ridges of the trace fossil *Planolites* Nicholson, occurring at the horizon of the conglomerate at Cedar Run (unit 49 of the type section). A quarter dollar gives the scale.

shows considerable secondary silica cementation, and authigenic quartz overgrowths are quite distinct (Figure 16J). The original quartz grains were clearly more rounded than in other parts of the Huntley Mountain Formation.

Other extraformational conglomerates are rare. Colton reports a "densely pebbly sandstone" at three localities in the Slate Run 7½-minute quadrangle at about 18 m (60 ft) above the conglomerate at Cedar Run (Colton and Luft, 1965). Colton also reports a medium-grained sandstone containing scattered granules and pebbles of milky quartz in the middle of his "upper sandstone sequence" in the southwestern part of the Cedar Run 7½-minute quadrangle (Colton, 1963a).

Nonred Fine Clastics

The red beds that appear at the top of fining-upward cycles are in many places interbedded with, or overlain by, nonred shale, claystone, or siltstone. Some fining-upward cycles are lacking red beds and have only nonred shale, claystone, or siltstone as an uppermost fine element. Nonred fine clastics occur elsewhere in the Huntley Mountain Formation simply as thin interbeds in dominantly sandstone sequences. The fine clastics include claystone, clay shale, silt shale, and siltstone; many gradations between

these four occur. Colors include medium dark gray (N4), medium gray (N5), light olive gray (5Y6/1 and 5Y5/2), olive gray (5Y3/2), dusky yellow (5Y6/4), grayish orange (10YR7/4), and greenish gray (5GY6/1). These colors are commonly mottled together with various shades of red, especially in the claystones and siltstones. Locally, grayish-black to dark-gray (N2 to N3) clay shale occurs in very thin beds. The clay shales are generally quite fissile, and the silt shales are fissile to subfissile; both disintegrate to platy, chippy, or hackly fragments. The claystones are nonfissile, and disintegrate to small, equant pieces or to hackly fragments. When wet, some of the claystones disintegrate to a soft, sticky, plastic clay. Many of the gray claystones exhibit rapid slaking characteristics, whereas the red claystones slake more slowly or not at all. The siltstones are nonfissile to subfissile, and disintegrate to hackly or rubbly fragments. Fairly well preserved plant fossils and some fossil conchostracans (a type of freshwater invertebrate) have been found in the nonred shales. Small-scale asymmetrical ripple bedding is a common sedimentary structure found in the nonred fine clastics, but the dominant bed form is even, parallel lamination.

Pisolith Beds

A most unusual lithology, which occurs sparsely within the Huntley Mountain Formation but has considerable paleoenvironmental importance, is the pisolith-bearing intraformational conglomerate. For the most part, there is little difference in composition between this lithology and the calcareous intraformational conglomerate described above, but the common occurrence of pisoliths does make it unique (Figure 21). "Pisoliths" are small, spheroidal, concentrically laminated, calcareous structures that may have been formed by algae, or by chemical precipitation. The pisoliths vary from 0.5 to 6.0 cm (0.2 to 2.4 in.) in diameter, and are most commonly 1.5 cm (0.6 in.) in diameter. They are spherical to somewhat irregular, but are, in most occurrences, distinct masses (Figure 22). The internal concentric lamination is most obvious on weathered specimens. Freshly broken specimens do not reveal the lamination as clearly.

The pisolith beds do not form resistant ledges, and generally form recesses as do the calcareous intraformational conglomerates. Shale, siltstone, and sandstone clasts are jumbled together with the pisoliths; the whole mass is bound together by a very calcareous, sandy matrix. The pisolith beds disintegrate to rubbly pieces.

CYCLICITY

Approximately nine major sedimentation cycles are present in the type section of the Huntley Mountain Formation. More complete exposure would allow more accurate delineation of the cycles. The average cycle thickness at the type section is 17.5 m (57 ft). The largest cycle is 30.6 m

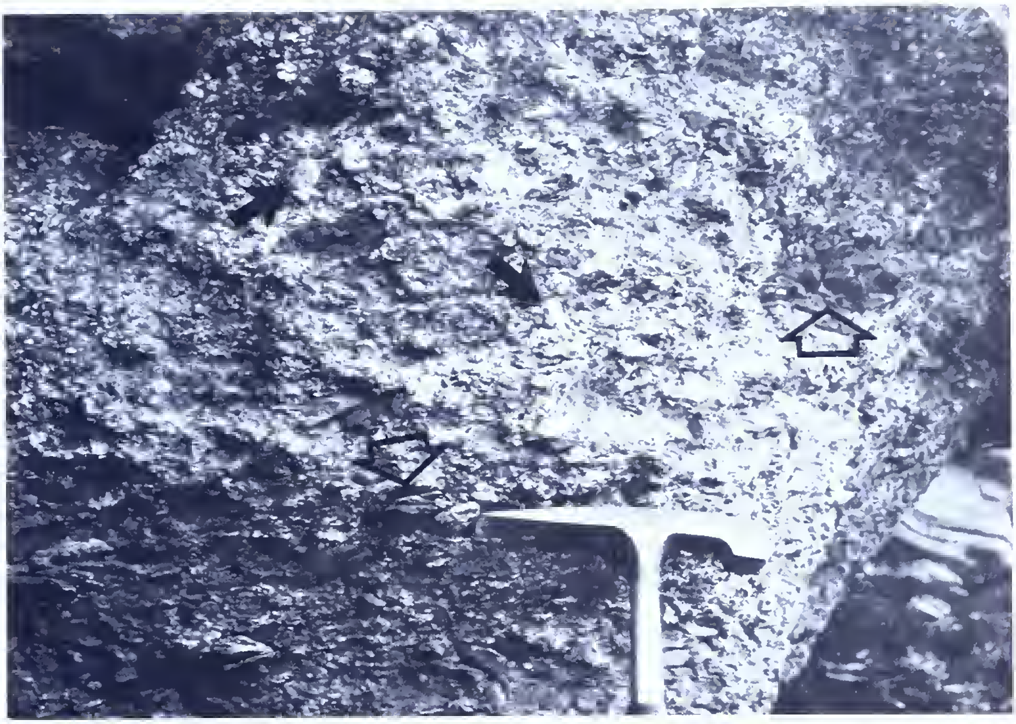

Figure 21. A close view of a pisolith bed at the base of the Huntley Mountain Formation (unit 28 of the type section). Pisoliths are white and round (black arrows). Shale clasts are gray, flat, and rounded (open arrows). A hammer gives the scale.

(100.4 ft) thick, and the smallest cycle is 6.6 m (21.7 ft) thick. The cycles (Figure 17) fine upward in grain size, as defined by Allen (1965, p. 229 ff.). They are made up of several phases or sediment elements stacked upon a disconformity, and arranged in a more or less grossly fining upward succession. The phases within the cycles fall into two principal categories as defined by Allen (1965, p. 241): a lower coarse member and an upper fine member. Coarse-member phases include conglomerate (intraformational or extraformational), large-scale cross-stratified sandstone, planar-bedded sandstone, and small-scale cross-stratified or ripple-bedded sandstone. Fine-member phases include small-scale cross-stratified or ripple-bedded siltstone (sometimes having very thin sandstone interbeds), shale beds, and claystone. Upper fine-member sediments may be red, nonred, or a combination of both. These elements or phases can be identified in the type section, and can be seen to fall into coarse-member to fine-member vertical arrangement. Other exposures of the Huntley Mountain Formation throughout north-central Pennsylvania display this fining-upward cyclic arrangement.

Not all cycles bear every phase. For example, the intraformational-conglomerate phase generally occurs at the base of a cycle, but many cycles lack

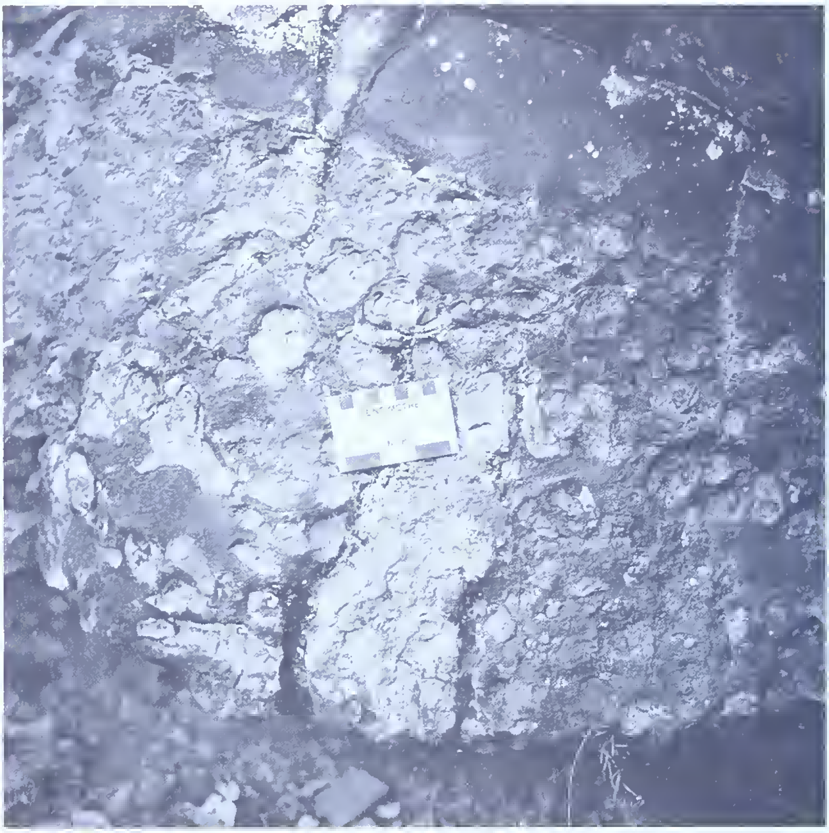

Figure 22. A pisolith bed in a roadcut in the Huntley Mountain Formation at 41°15′07″N/77°36′44″W, along Pa. Route 120 in the Glen Union quadrangle, Clinton County. The scale is divided in centimeters and inches.

conglomerate. The uppermost shale and claystone phase of a cycle may be absent. All cycles have at least some of the phases of the lower coarse member and the upper fine member. In most places, the upper fine member is quite thin (less than 1 m) and may be represented only by ripple-bedded nonred silt shale. The lower coarse member is everywhere the thickest part of a cycle.

Some repetitions or subcycles in the major cycles exist. For example, a thin lens of intraformational conglomerate may appear as a minor break in a cross-stratified sandstone sequence, well above the basal disconformity. Alternations of planar-bedded and cross-stratified sandstone are repetitions of two phases within the lower coarse member of a cycle. Repetition of siltstone grading up through shale to claystone may occur several times as nested subcycles within the upper fine member of a cycle.

The apparent cyclicity of the Huntley Mountain Formation may break down at about the horizon of the conglomerate at Cedar Run. Because this is probably a marine element in the succession, the fluvial processes that

gave rise to fining-upward cycles probably temporarily changed to distal-river-mouth-bar or offshore-bar processes.

The Burgoon Sandstone contains no fining-upward cycles, and, as such, stands in clear contrast to the Huntley Mountain Formation. The Catskill Formation contains many fining-upward cycles, particularly in the upper part. Observation of many Catskill outcrops and sections below the Huntley Mountain indicates that Catskill cycles generally have larger upper fine members that contain a greater abundance of red siltstone.

GEOMORPHIC EXPRESSION

The Huntley Mountain Formation weathers to a series of small cliffs or very steep slopes, separated by benches or very gentle slopes. The cliffs or steep slopes are underlain by the resistant sandstones, and the benches are underlain by red beds or nonred fine clastics. This geomorphic expression gives the impression of an intricate staircase or a wedding cake, and is fairly easy to recognize on aerial photographs (Figure 23). Where the resistant ledges and benches are not well formed, the presence of lines of springs located at the red-bed horizons gives a horizontally striped vegetation pattern on the aerial photographs.

The overlying Burgoon Sandstone has a very distinctive, thick, massive form on aerial photographs, and is generally very easy to identify. It is commonly expressed as a pair of cliff-forming units that stand out boldly in contrast to the smaller cliffs and ledges of the Huntley Mountain Formation. In most places, the underlying Catskill Formation displays a gentler and more rolling topography than does the overlying Huntley Mountain. This expression is due to the greater proportion of red shales and siltstones in the Catskill. Where there are a greater-than-average number of sandstones in the upper Catskill, it is difficult, if not impossible, to distinguish Huntley Mountain from Catskill on the basis of geomorphic expression alone as seen on aerial photographs.

BOUNDARIES

CATSKILL-HUNTLEY MOUNTAIN BOUNDARY

The upper limit of the Catskill Formation used herein follows the usage of Colton (1968), who mapped the top of his "red-bed sequence" as the highest occurrence of red sandstone. This is the most useful key to drawing the base of the Huntley Mountain Formation. Broadly speaking, the Huntley Mountain has a greater proportion of sandstone than the Catskill, and the geomorphic expression of the Huntley Mountain tends to bear this out. But, in practice, it is sometimes difficult to separate Catskill from Huntley Mountain, and the sandstone color becomes a very important criterion for

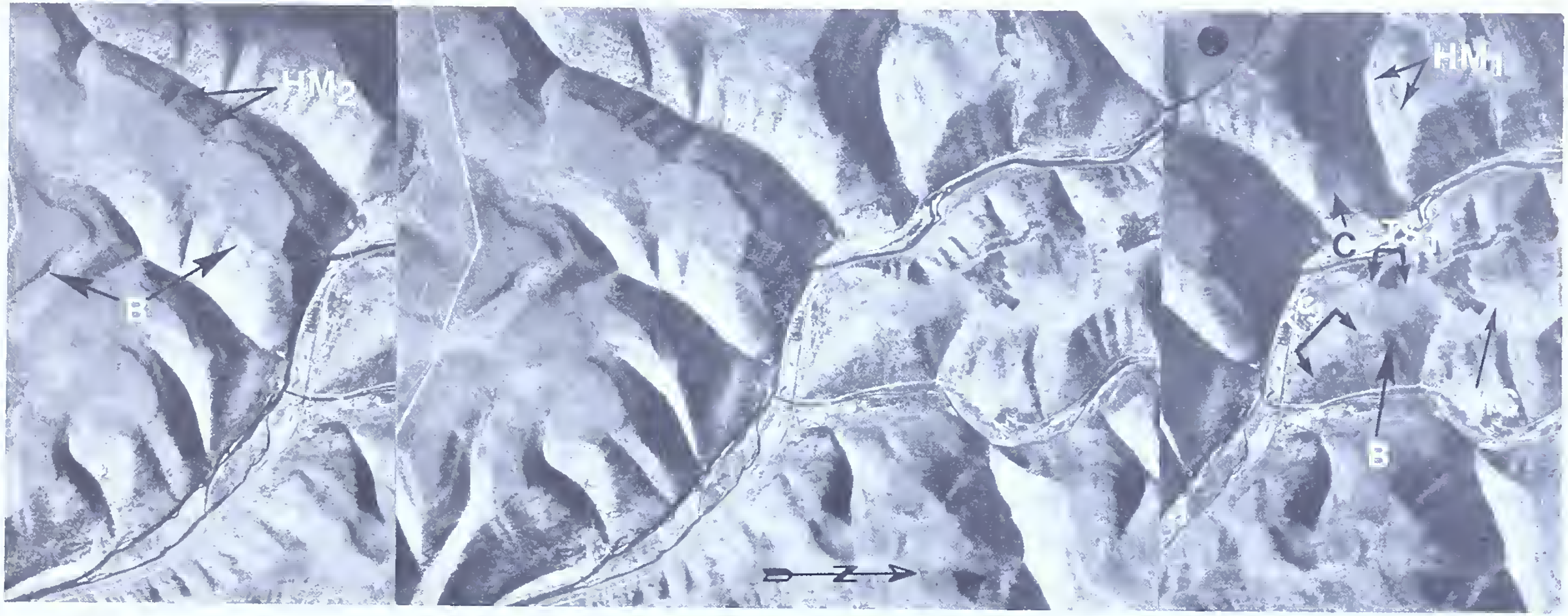

Figure 23. A stereo triplet showing the geomorphic expression of the Huntley Mountain Formation and vertically adjacent strata. Note the "banded" appearance of the Huntley Mountain Formation at HM_1 and the tiered slope at HM_2. The base of the Burgoon Sandstone is at B. The base of the Catskill Formation and a change to the more subdued topography of the Catskill is at C. The base of the Mauch Chunk Formation is at MC. The type section of the Huntley Mountain Formation is at TS; the supplemental section is at TS_1. The aerial photographs were taken for the U. S. Geological Survey on January 21, 1973, from 38,000 feet (11,582 m) above mean ground. The town of Waterville is at the center of the triplet; the area covers parts of the Waterville and Jersey Mills quadrangles in western Lycoming County.

differentiation. Huntley Mountain sandstones are more strikingly greenish gray and light olive gray, whereas Catskill sandstones are normally medium dark gray with some greenish-gray cast, grayish red, and brownish gray. Locally, brownish-gray (5YR4/1), very fine grained sandstone may be found in the Huntley Mountain Formation, but no grayish-red (5R4/2) sandstone has been observed.

HUNTLEY MOUNTAIN-BURGOON BOUNDARY

The Burgoon Sandstone is characterized by medium-grained, buff, strongly trough crossbedded sandstone, having no red-bed components. Greenish gray and light olive gray are not typical Burgoon colors. The Burgoon is commonly conglomeratic near the base, having quartz pebbles that average less than 1 cm (0.4 in.) in diameter. In many places, this conglomeratic sandstone rests directly on the "Patton" red beds and forms a clear-cut and easily mappable contact. Where the "Patton" is missing, it is still fairly easy to distinguish the fine-grained, light-olive-gray, flaggy, thin-bedded sandstone of the Huntley Mountain Formation from the overlying Burgoon. Locally, the Huntley Mountain sandstones are medium grained, and do tend to have a buff appearance. In this case, observation of crossbedding style usually reveals that Huntley Mountain sandstones are much more gently crossbedded, and at a lower angle. Troughs in the Huntley Mountain do not have as great an amplitude as Burgoon Sandstone troughs. Planar bedding and platy or flaggy fragmentation are more typical of the Huntley Mountain. Slabby, rubbly, and blocky fragmentation are more typical of the Burgoon.

In the Elkland-Tioga area, Fuller and Alden (1903b) reported that the combined "Pocono" and "Oswayo" are approximately 1,000 feet (305 m) thick. This stratigraphic interval (which is the Huntley Mountain Formation) seems excessively thick; the excessive thickness may be due to a northern lateral gradation of the Burgoon Sandstone to an upward continuation of the Huntley Mountain Formation. However, such a facies relation has not been firmly established.

HUNTLEY MOUNTAIN-SPECHTY KOPF BOUNDARY

The Spechty Kopf Formation includes the clastic succession between the Catskill and Pocono Formations of eastern Pennsylvania. Spechty Kopf sandstones are similar to overlying Pocono sandstones, and separation of the Pocono and Spechty Kopf hinges partly on recognition and mapping of the basal conglomerate of the Beckville Member of the Pocono Formation. The Spechty Kopf sandstones are also likely to be yellowish gray, olive gray, or brownish gray in contrast to the dominantly yellowish gray or light to medium gray of the Pocono. The Spechty Kopf Formation is separated

from the Huntley Mountain Formation at the Milton anticline (Figure 24), northwest of the Lackawanna syncline. This location is chosen partly because rocks of the Huntley Mountain-Spechty Kopf interval are missing by erosion, and the anticline forms a convenient natural break. The Huntley Mountain sandstones, as a general rule, are more greenish gray in contrast to the olive, yellowish, and buff colors of the Spechty Kopf. Minor red beds occur in the Spechty Kopf and do not serve as a criterion of distinction from the Huntley Mountain. The Spechty Kopf Formation has a polymictic diamictite of variable thickness and distribution at the base. A *polymictic diamictite* is a nonsorted or poorly sorted, noncalcareous, sedimentary rock containing a wide variety of particle sizes and particle compositions. The Huntley Mountain Formation bears no such lithology. The base of the Spechty Kopf is in part an unconformity; no unconformity is recognized at the base of the Huntley Mountain.

HUNTLEY MOUNTAIN-ROCKWELL ARBITRARY CUTOFF

The Rockwell Formation was named in Maryland and West Virginia by Stose and Swartz (1912, p. 13). There, the Rockwell comprises arkosic sandstone, some conglomerate, and buff, hackly shale. It rests directly on the Hampshire Formation which is equivalent to the Catskill. It is overlain by the Purslane Formation which is herein considered the lithostratigraphic equivalent of the Burgoon Sandstone. The term Rockwell was carried into Pennsylvania for the 1980 Pennsylvania state geologic map (Berg and others, 1980) after the reference section at Sideling Hill on the north side of the Potomac River was reexamined. The buff sandstones and interbedded dark shales are persistent in character into Pennsylvania, at least to the region north of Altoona. The Burgoon and the Rockwell together make up what was formerly termed "Pocono" in south-central Pennsylvania. "Oswayo" was never carried into this part of Pennsylvania; its "disappearance" along the Allegheny Front in Centre County was never fully explained. It is at about this location that the Huntley Mountain Formation grades southward into the Rockwell Formation. The overlying Burgoon and underlying Catskill carry through as clearly mappable units. An arbitrary vertical cutoff between Huntley Mountain and Rockwell is herein defined at 41° north latitude (Figure 24). Eventual adjustment of the geographic location of this vertical cutoff may result from more detailed mapping.

Rockwell Formation sandstones are medium light gray or light olive gray to buff and are in some places difficult to distinguish from Burgoon sandstones. Some thin red shales and greenish shales have been recorded in exposures along the railroad tracks in Sugar Run, east of Gallitzin, Pennsylvania (Swartz, 1965, p. 30). Reger (1927, p. 398 ff.) reported brown shales, greenish-gray and gray sandstones, red variegated shales, and a greenish-

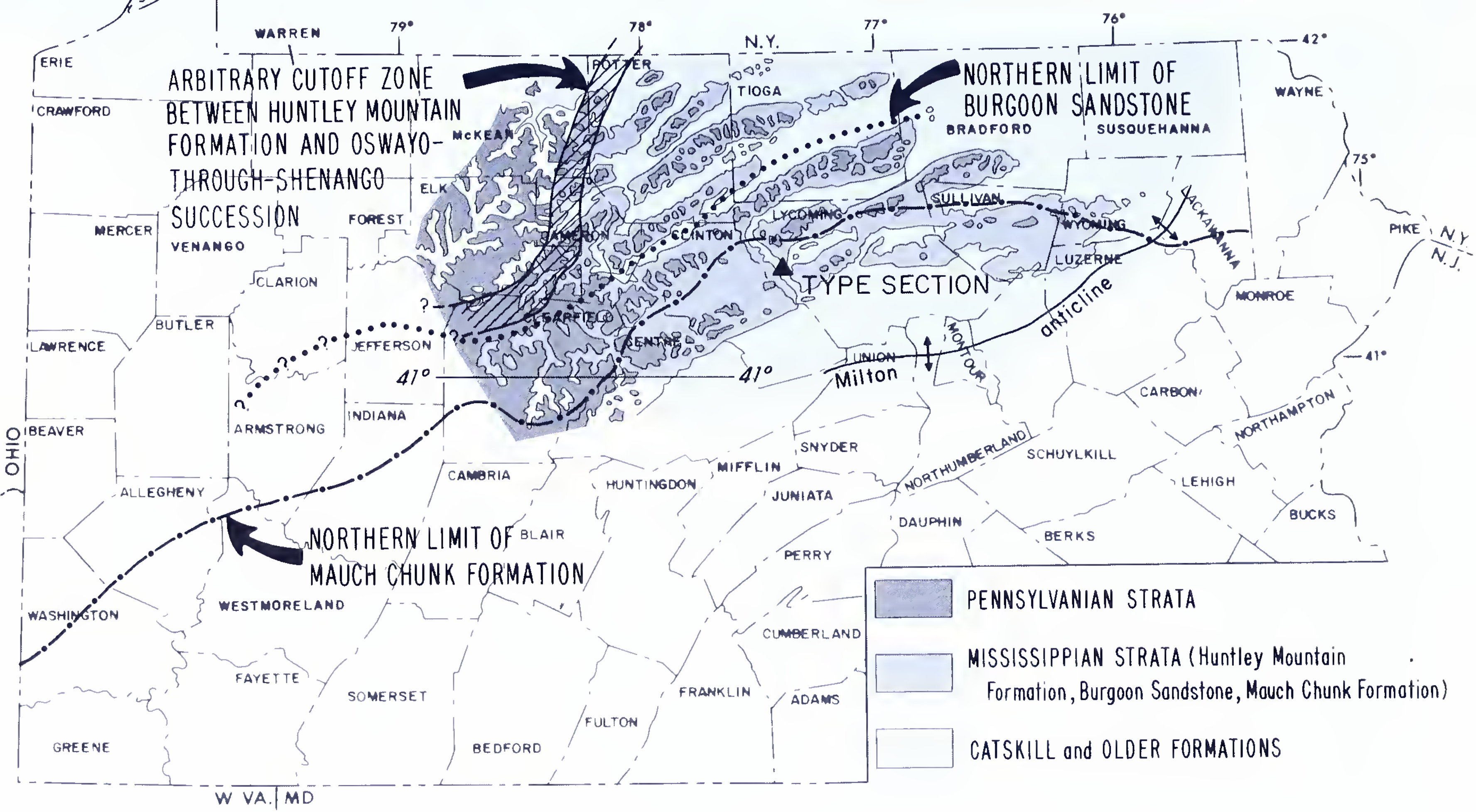

Figure 24. Map showing the extent of Mississippian rocks in north-central Pennsylvania. Lateral boundaries of the Huntley Mountain Formation are indicated, along with northern limit lines for the Burgoon Sandstone and Mauch Chunk Formation.

black or bluish-black shale containing marine fossils in the sub-Burgoon sequence above the Catskill Formation in the Broad Top basin of south-central Pennsylvania. Sevon (1979, p. 61 ff.) has documented the occurrence of polymictic diamictite in the lower Rockwell Formation in eastern Bedford County. The Rockwell therefore includes a greater variety of lithologies, notably a marine shale and a diamictite, and also some scattered extraformational conglomerates. The Huntley Mountain Formation does not display the same degree of lithologic variety. Further, the Rockwell Formation does not appear to have fining-upward cycles, whereas the Huntley Mountain does. The Rockwell does not have the preponderance of greenish-gray flaggy sandstone that the Huntley Mountain does.

ARBITRARY CUTOFF BETWEEN HUNTLEY MOUNTAIN FORMATION AND OSWAYO-THROUGH-SHENANGO SUCCESSION

The western limit of the Huntley Mountain is roughly the western limit of post-Catskill nonmarine deposition. In practice, this is a complex interdigitation of marine and nonmarine strata that is difficult to delineate. For purposes of revising the 1980 state geologic map (Berg and others, 1980) at a scale of 1:250,000, the authors have established a zone about 7 to 8 km (4 to 5 mi) wide which represents the average horizontal space required to accomplish complete regression and change to the marine succession of western Pennsylvania. In essence, this zone is a nonvertical arbitrary cutoff. The zone, which is shown in Figure 24, runs southward from western Potter County through central Cameron County, changes to a westward trend in eastern Elk County, and crosses the northwest corner of Clearfield County. The southward continuation of this zone of regression is a subsurface problem which is not resolved.

Detailed mapping in this part of Pennsylvania will probably result in an intricate stratigraphic subdivision reflecting interbedding of offshore marine clastics and nonmarine delta-plain sediments. The Devonian Oswayo Formation is discussed by Glenn (1903, p. 978-980) and Tesmer (1975, p. 76-78). The Oswayo includes gray and olive-green shales, interbedded with thin siltstones and sandstones. Fossil brachiopods and other marine fossils are abundant, and coquinites (compact rocks made almost wholly of fossils) are found in several places. The Mississippian formations above the Oswayo Formation include (upward) the Cussewago Sandstone, Bedford Shale, Corry Sandstone (Berea Sandstone farther west), Cuyahoga Group, and Shenango Formation. These formations are a dominantly marine succession. Some beds within the Shenango are probably of lower delta plain origin, and, as such, might be confused with the sandstones of the Burgoon, but the Shenango has interbedded marine shales and has an upper shaly member that bears marine fossils. The Mississippian strata of northwestern

Pennsylvania are described by Schiner and Kimmel (1972). The Huntley Mountain Formation is the dominantly nonmarine lateral equivalent of the marine Oswayo and overlying marine Cussewago through Shenango.

CONTACT WITH THE POTTSVILLE GROUP

Pre-Pennsylvanian erosion removed a large part of the Mississippian strata in Pennsylvania before sandstones of the Pottsville Group were deposited. This erosion produced an unconformity which transects older and older rocks in a northward direction. In south-central Pennsylvania, the Pottsville rests on the Mississippian Mauch Chunk Formation, and the underlying Burgoon Sandstone and Rockwell Formation are present in their entirety. In central Clearfield County, the Mauch Chunk is absent and the Pottsville rests on Burgoon Sandstone. In northernmost Clearfield County, the Pottsville rests on the Huntley Mountain Formation, and the Burgoon is absent. In southwestern New York State, the northernmost outliers of the Pottsville rest on Devonian rocks, and Mississippian rocks are missing. In Figure 24, the northern limit of the Mauch Chunk Formation and the northern limit of the Burgoon Sandstone are shown. North of the Burgoon limit, the Pottsville Group sandstones and conglomerates rest directly on an eroded Huntley Mountain Formation (or western marine equivalent). The basal Pottsville conglomerate, usually called the Olean Conglomerate in north-central Pennsylvania, in many places has quartz pebbles over 5 cm (2 in.) in diameter. An understanding of regional relationships as shown in Figure 24 lessens the possibility of confusing the Pottsville conglomerates with the Burgoon Sandstone.

PALEONTOLOGY AND AGE

PLANT FOSSILS

Fossil plants, in the form of stem or branch fragments (Figure 25) or finely comminuted debris, are common at various stratigraphic positions in the Huntley Mountain Formation. Fossil leaves are generally scarce, but sometimes occur in silt shale or clay shale beds. At the type section, fossil leaves were collected from supplemental section unit 7, and from main section unit 46. These fossil leaves were examined by Dr. James D. Grierson of the State University of New York at Binghamton.

Grierson (personal communication, 1978) identified several pinnules from supplemental section unit 7 as belonging to the genus *Adiantites*. Some specimens may possibly be identified as *A. spectabilis* Read (Figure 26) or as *A. cardiopteroides* Read, but better preservation and more fossil material would be required for a final identification. Unit 7 of the supple-

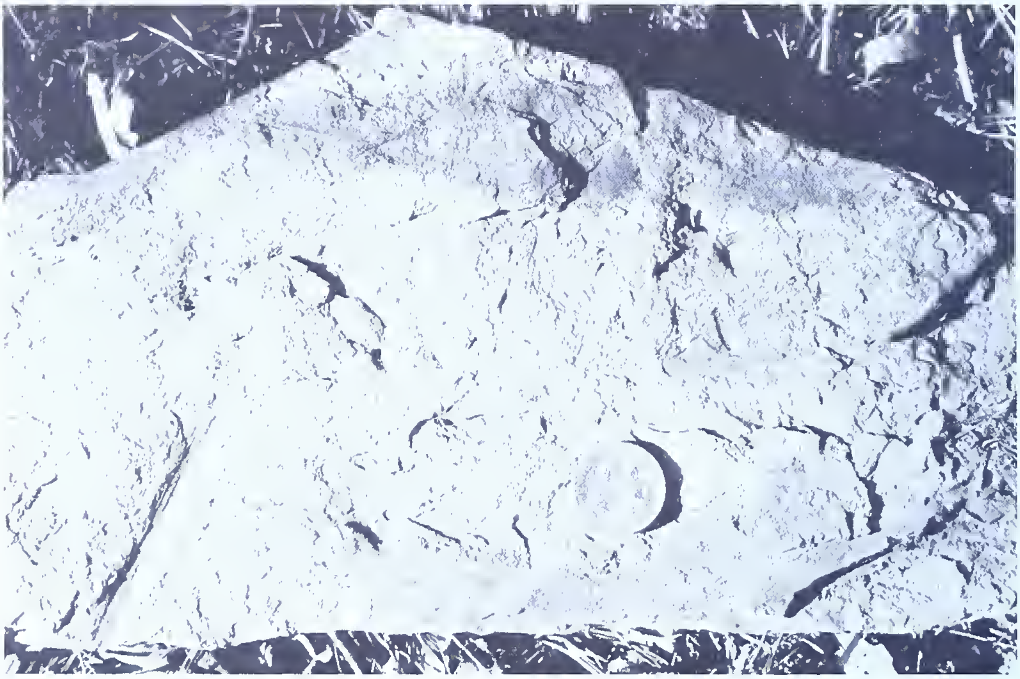

Figure 25. Fossil plant fragments in the Huntley Mountain Formation (unit 46 of the type section). A quarter dollar gives the scale.

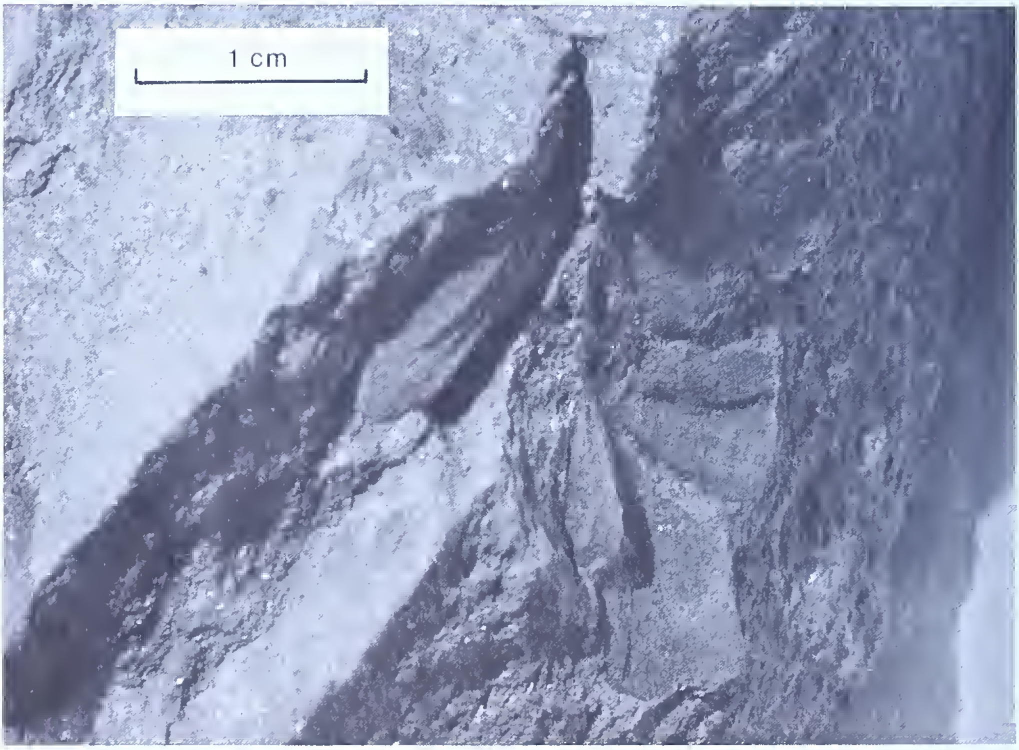

Figure 26. *Adiantites* sp. cf. *A. spectabilis* Read from a siltstone lens in the Huntley Mountain Formation, supplemental type section, unit 7.

mental section is just below the "Patton" red shale, which is about 0.5 m (1.6 ft) thick and directly underlies the Burgoon Sandstone.

Grierson also attempted identification of the dichotomously veined leaves or pinnules from unit 46 of the main section, but could only guess that they were possible species of *Archaeopteris* (Figures 27 and 28). Grierson points

Figure 27. ?*Archaeopteris* from silt shale of the Huntley Mountain Formation, main type section, unit 46. Note the dichotomous venation on pinnules.

out that the genera *Archaeopteris*, *Rhacopteris*, *Sphenopteris*, *Eryopsis*, and *Rhodea* all had leaves or pinnules that had dichotomous venation. He further points out that some species of *Adiantites*, *Triphyllopteris*, *Ginkgoites*, *Eddya*, *Psygmophyllum*, and *Enigmophyton* also had leaves or pinnules that had dichotomous venation. Grierson explains that when leaves of all these genera are not *in attachment* (to parent axes), very little can be said about age except that they can be any age from Middle Devonian to Permian. Thus the materials recovered from unit 46 of the main section are too fragmentary to be unquestionably identified as Late Devonian, and are too fragmentary not to be confused with similar fossils from Zones 1, 2, and 3 of the Mississippian flora.

Figure 28. *?Archaeopteris* from silt shale of the Huntley Mountain Formation, main type section, unit 46.

Aside from the problem of fragmentary material, Grierson explains (written communication, 1978) that

> . . . in the case of *Archaeopteris* recent work (Carluccio, Hueber & Banks, 1966; Beck, 1971) has shown that the large fern-like "frond" that was the earlier concept of the vegetation is, in reality, a lateral branch system that bears on successively smaller branches, dichotomously veined leaves (the pinnules of the earlier concept). Also contrary to earlier views it has been shown that the leaves are spirally arranged on both the ultimate and penultimate branches. Thus the earlier concept of a flattened "frond" was a misconception. As might be expected, the leaves vary to some degree in size and morphology on different orders of branching as well as with their position on the tree. Thus the numerous species of *Archaeopteris* that have been named on the basis of pinnule size and morphology may reflect their position in the canopy of an *Archaeopteris* tree, or even reflect environmental conditions rather than true biological relationships.

Grierson says further that:

> Another problem with *Archaeopteris* is that its range is not strictly Upper Devonian as is commonly reported. There are reports of *Archaeopteris* (sometimes called *Rhacopteris latifolia*) from the Horseshoe Curve at Altoona with a flora otherwise suggesting Zones 1 or 2 of Read & Mamay, 1964 (see also Arnold 1939, Read 1955, Carluccio 1966). The petrified axes of *Archaeopteris*, when found separately, are placed in the form genus *Callixylon*. *Callixylon* is reported from Middle Devonian to Lower Mississippian.

Thus, even if a positive identification of specimens from unit 46 of the main section as *Archaeopteris* could be made, that would not be absolute proof that unit 46 is Late Devonian.

If better paleobotanical materials can be found, then the Devonian-Mississippian systemic boundary may be more accurately located within the Huntley Mountain Formation.

INVERTEBRATE FOSSILS

Brachiopoda

A few fossil brachiopods were collected from float blocks of the conglomerate at Cedar Run, at the type section of the Huntley Mountain Formation. Ebright (1952, p. 31) mentioned the presence of a few fragments of brachiopods at about this horizon in his measured section at Huntley Mountain (Waterville). The brachiopods are enclosed in coarse conglomeratic sandstone, and are not well preserved. One specimen (Figure 29) is similar to brachiopods identified from the Knapp Formation by Holland (1958) as *Syringothyris angulata* Simpson. In the Bradford-Warren area, Holland placed the Mississippian-Devonian systemic boundary at the horizon having

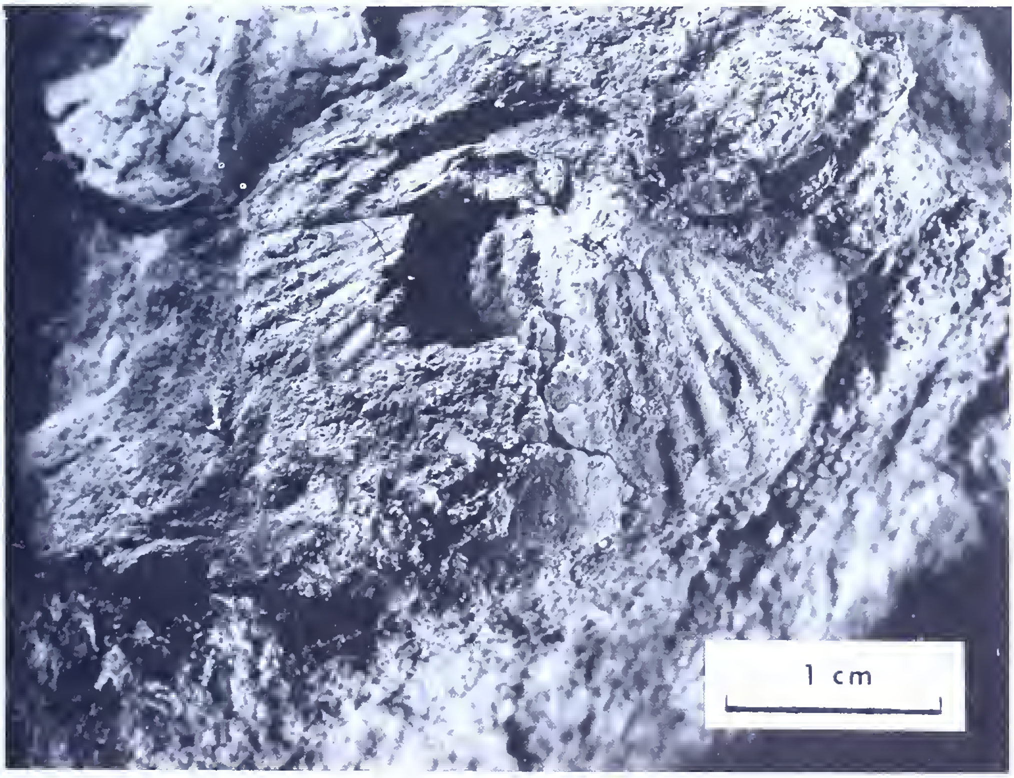

Figure 29. ?*Syringothyris* from the conglomerate at Cedar Run, main type section, unit 49.

the greatest number of new brachiopod forms. Chief among these forms are the genera *Dictyoclostus* and *Syringothyris*. Holland (1958, p. 77) said that these genera occur abundantly in the Mississippian strata, but not in Devonian strata (Oswayo Formation). Further sampling at the horizon of the conglomerate at Cedar Run is necessary, and detailed studies are needed to verify the presence of the family Syringothyrididae.

Bivalvia

In the Salladasburg quadrangle, in western Lycoming County, Faill and others (1977, p. 12) reported the occurrence of a small fossil bivalve, *Spathella*, cf. *S. typica* Hall, in the "lower member" of the Pocono Formation. Their "lower member" is stratigraphically equivalent to the Huntley Mountain Formation. The bivalves were collected from about 80 m (260 ft) below the Burgoon Sandstone at Pond Hollow. *Spathella* ranges through the Upper Devonian and Mississippian and is a genus of the order Modiomorphoida, which is thought to be marine. If *Spathella* is actually marine, it must be very marginally marine, because no other marine fossils were found in association with it. Faill and others (1977, p. 13) reported plant fossils in association with these fossil bivalves.

Conchostraca

In the English Center quadrangle, in northwestern Lycoming County, some fossil conchostracans were found by the authors in thin beds of light-olive-gray silt shale, at about 76 m (250 ft) below the base of the Burgoon Sandstone. The collecting site is along Schoolhouse Road, up Schoolhouse Hollow, northwest of Little Pine Creek, at 41°24′17″N/77°21′36″W. The conchostracans, which are very small, thin-shelled arthropods, are identified here as *?Cyzicus* (Figure 30). The superfamily Cyzicoidea ranges from Early Devonian to Recent, and can serve as useful index fossils, but many well-preserved specimens would have to be collected, examined, and measured. In general, the conchostraca are freshwater arthropods.

TRACE FOSSILS

Trace fossils, the markings left in sediment by the activity of organisms living at the time of deposition, are not uncommon in the shales of the Huntley Mountain Formation. For the most part, the trace fossils are very subtle and quite small, and are generally faint trails or small burrows. These are unidentified at present because considerable research needs to be done in the area of minute traces in Devonian and Mississippian freshwater shales. Three trace fossils that are larger merit documentation here.

One very interesting trace is a large cylindrical structure thought to be the fossil burrow formed by the aestivating activity (remaining in a suspended

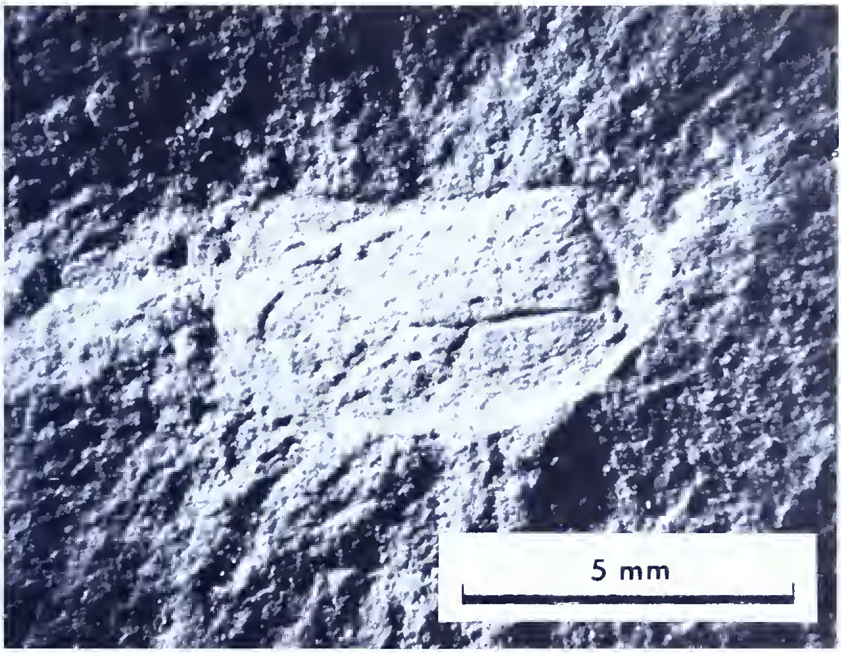

Figure 30. ?*Cyzicus* from Huntley Mountain Formation silt shale 76 m (250 ft) below the Burgoon Sandstone in the English Center quadrangle, Lycoming County.

state during dry periods) of Devonian lungfish. These burrows vary in diameter from about 3 cm (1.2 in.) to 12 cm (4.7 in.). They range in length up to a maximum of about a meter (3 ft). They occur most commonly in red siltstone or shale, in the upper parts of fining-upward cycles. The best examples (Figures 31 and 32) may be seen in the roadcut south of Forksville, Sullivan County, at 41°28′53″N/76°35′36″W in the Eagles Mere quadrangle. The burrows occur about 168 m (550 ft) below the base of the Burgoon Sandstone. Several other occurrences of aestivation burrows in the lower half of the Huntley Mountain Formation have been noted by the authors. These burrow structures are more common in the underlying Catskill Formation and were first documented by Woodrow and Fletcher (1968). Such trace fossils attest to a freshwater depositional environment.

A smaller trace fossil was found in float of thin sandstones associated with the conglomerate at Cedar Run. The fossil occurs as irregular hypichnial ridges and burrow casts which are 0.3 to 0.8 cm (0.1 to 0.3 in.) in diameter. Some of the ridges show irregular branching patterns. This fossil (Figure 20) is identified as *Planolites* Nicholson. Where *Planolites* has been studied elsewhere in the world, it is associated with marine deposits. At present, no significant geologic time value can be assigned to this trace; it ranges throughout the Paleozoic and Mesozoic, and probably through the Cenozoic. It is likely the result of marine worms living in a shallow, tidal or subtidal environment.

Figure 31. Aestivation burrow (vertical expression) in the lower part of the Huntley Mountain Formation near Forksville, Sullivan County.

Another large trace fossil, probably classifiable as a crawling trace (Repichnia), was found at 41°39′44″N/76°41′38″W in the Leroy quadrangle, about 2 km (1.25 mi) southeast of the village of Leroy in Bradford County. The fossil was collected at about 75 m (250 ft) below the Burgoon Sandstone in what Woodrow (1968) mapped as the upper part of his "Sunfish" Formation. The organism that made this trace may have had legs or sharp appendages (claws?) as is indicated by the sharp grooves along the edge of the trace (Figure 33). The best interpretation the authors can make at present is that a large arthropod produced the trace fossil.

DEPOSITIONAL ENVIRONMENTS

The presence of fining-upward cycles, predominant trough crossbedding style in the sandstones, fossil plants and roots, and fossil freshwater inverte-

Figure 32. Aestivation burrows (horizontal expression) in the lower part of the Huntley Mountain Formation near Forksville, Sullivan County. The scale is divided in centimeters and inches.

brates all point to an alluvial environment of deposition for most of the Huntley Mountain Formation. An exception to this generalization is the conglomerate at Cedar Run, which contains marine fossils. This conglomerate marks a very rapid marine transgression across a fluvial system, and suggests that some of the strata immediately subjacent and/or superjacent to the Cedar Run conglomerate are the result of nearshore or tidal-flat depositional processes. Indeed, the trace fossil *Planolites* found in association with the Cedar Run (Figure 20) may be characteristic of tidal flats. In the zone where the Huntley Mountain passes to the west into the marine Oswayo-through-Shenango succession, interpreted depositional environments are complex, and probably involve nearshore, tidal-flat, and lower delta plain environments.

The fining-upward cycles of the upper part of the underlying Catskill Formation are most likely the result of deposition by a meandering river system. The upper fine elements in the Catskill cycles are red shales and siltstones, and these were deposited on overbanks during periods of flooding. The lower coarse elements in Catskill cycles are crossbedded or planar-bedded sandstones, containing some intraformational conglomerate in

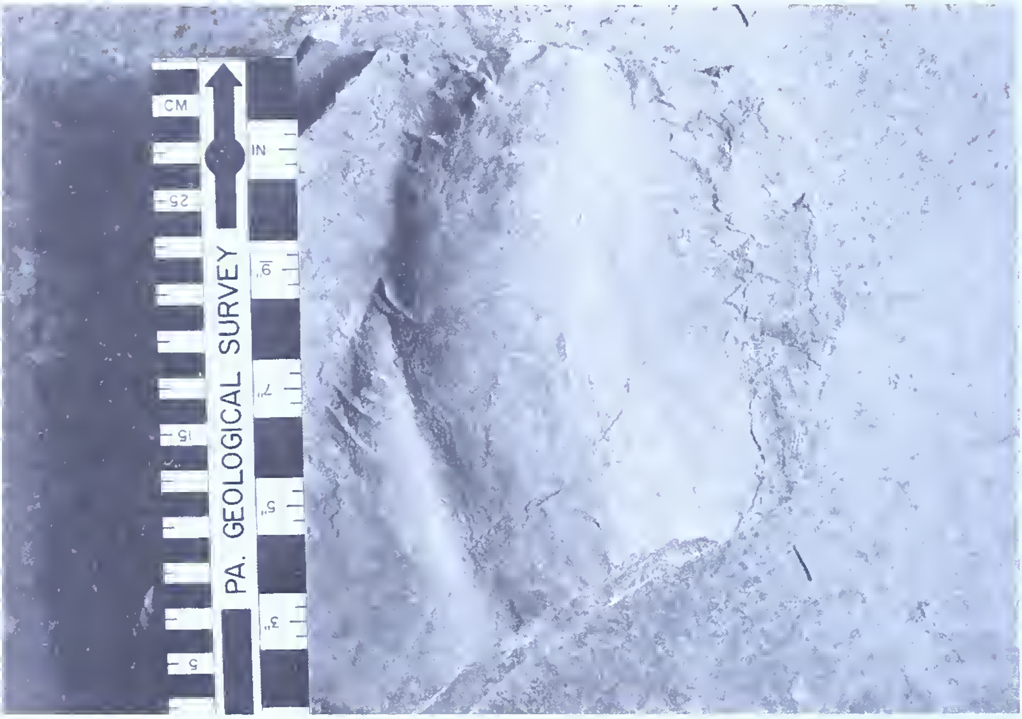

Figure 33. Repichnia from Huntley Mountain Formation sandstone southeast of Leroy, Bradford County. The scale is divided in centimeters and inches.

places; these were deposited as channel sediments during normal river flow. The fining-upward cycles are preserved in meander systems because channels maintain their position long enough for floodplain deposits to become stabilized and vegetated.

In contrast to meandering-river systems, braided-river systems are characterized by rapidly changing flow conditions, a paucity of fine-grained overbank sediment, and ephemeral channel patterns. The Burgoon Sandstone is probably the result of deposition in a braided-river system. Fine overbank shale or siltstone in fining-upward cycles is lacking in the Burgoon. Smith (1970, p. 3010) indicated that thin, lenticular shales and shale clasts occur randomly in braided-stream deposits. Thin, random shale lenses do occur in the Burgoon, as do shale clasts. The crossbedding observed in the Burgoon is well developed and consistently in trough-shaped sets. Cut-and-fill structures are common.

The Huntley Mountain Formation is transitional in its physical attributes between the Catskill Formation and the Burgoon Sandstone. The ancient environments responsible for Huntley Mountain deposition are probably transitional between those attributable to the Catskill and to the Burgoon. In all likelihood, because of the presence of fining-upward cycles, the major depositional environment of the Huntley Mountain was a meandering-river

system that was carrying a greater average sand load than the Catskill meandering-river system. The upper fine (overbank) elements of Huntley Mountain cycles are thinner in general than those of Catskill cycles; lower sand (channel) elements are thicker than those of Catskill cycles. Overbank deposits were given less time to stabilize, and channel stability was lower, leading to more rapid migration of meanders. Channelways were more ephemeral than Catskill channels, and a braid system was approached during Huntley Mountain time. The upper parts of the Huntley Mountain may contain true braided-river deposits—precursors of the Burgoon braided-river system.

The brief marine transgression of the conglomerate at Cedar Run affected only the western portion of the full extent of the Huntley Mountain Formation. Colton (1963b, p. 121) showed that the conglomerate extended in an irregular pattern no farther east than western Lycoming County and southwestern Tioga County. More detailed studies are needed to accurately delineate how a brief marine transgression affected the meandering-river systems of the western part of the Huntley Mountain.

The Huntley Mountain Formation was deposited in the restricted extreme northern end of the Appalachian basin. The setting was more distant from the Acadian source area to the east and southeast than in the case of the correlative Spechty Kopf and Rockwell Formations. In addition, the Huntley Mountain may have been receiving some input from the older Taconic highlands to the northeast, and possibly from the craton to the north.

Sediments of the Huntley Mountain Formation were deposited upon the upper surface of the vast red delta complex of the Catskill Formation. The Catskill delta complex and its westward marine equivalents were essentially a prograding depositional sequence which achieved maximum western extension during the late part of the Late Devonian (Chautauquan). At that time, a widespread and relatively abrupt marine transgression overran the upper surface of the Catskill delta complex, resulting in the deposition of the marine Oswayo Formation. This transgression is somehow reflected farther to the east by the change from Catskill deposition to Huntley Mountain deposition. How the greater sand input and presumed increased streamflow velocity of the Huntley Mountain depositional system is related to an abrupt transgression farther west is not clear at present. Perhaps increased precipitation and a rise in sea level are linked at this moment of geologic time.

ECONOMIC GEOLOGY

CLAYSTONE AND CLAY SHALE

The claystone and clay shale beds occurring as overbank deposits at the tops of fining-upward cycles are clearly subeconomic at present because of

their thinness and generally inaccessible position on the steep slopes formed by the Huntley Mountain Formation. The red shales of the underlying Catskill Formation are thicker and more easily accessible. Leighton (1941, p. 173) suggested that the Catskill shales of Lycoming County are similar to those of Clinton County, which have proved to be good for face brick manufacture. On the basis of physical similarity and general similarity of origin, the Huntley Mountain claystone and clay shale deposits may give test results similar to those of the same kinds of deposits that occur in the Catskill Formation.

The "Patton" red shale beds in the Huntley Mountain just beneath the Burgoon Sandstone in the Clearfield County area are unusually thick. Some beds of shale and claystone are up to about 8 m (25 ft) thick and are laterally extensive. Test results on one of the shale beds were given by Edmunds and Berg (1971, p. 113); the potential use indicated is for face brick.

FLAGSTONE

Many small flagstone quarries were formerly opened at various levels within the Huntley Mountain Formation throughout its areal extent. The flagstone is generally thin, splits easily, has an attractive green color, and is of medium quality. The stone does not compare with that produced in northeastern Pennsylvania (Pike, Wayne, and Susquehanna Counties) from the Catskill Formation. The Huntley Mountain sandstone seems to be less well indurated, containing more clay minerals and mica. The Catskill Formation underlying the Huntley Mountain has also been quarried for flagstone; it appears to be similar in quality to the overlying Huntley Mountain, but is frequently grayish red to brownish gray. Colton (1968) observed that the rock most suitable for commercial grade flagging (and most often quarried) occurs in his "lower sandstone sequence" just above or below the red shale unit called "Mount Pleasant" by Ebright (unit 41 of the Huntley Mountain type section). To the authors' knowledge, only one quarry (Figure 6) was intermittently active during preparation of this report. The quarry is located along the road ascending to Barclay, about 3 km (2 mi) southwest of Franklin Center in the Powell quadrangle (41°41′04″N/76°36′05″W).

STRUCTURAL DATUM PLANES

At least two stratigraphic horizons have proven valuable for drawing detailed surface structure contour maps in the region underlain by the Huntley Mountain Formation. Colton (1967) successfully mapped detailed structure in parts of Lycoming, Tioga, Potter, and Clinton Counties by plotting all known elevations of the conglomerate at Cedar Run and the base of the Burgoon Sandstone (top of Huntley Mountain or "Patton" red shale). Fur-

ther structural mapping to the east can be carried out utilizing these horizons, and it may be possible to define other important structural datum planes within the Huntley Mountain that will be useful for mapping. The economic impact of this mapping will most likely be felt in the area of natural-gas exploration, although regional development of groundwater supplies will also benefit.

URANIUM

During measurement of the type section at Huntley Mountain, all lithologies were checked with a Geiger counter. No obvious anomalies were detected. The shales gave the highest readings, but these were not unusual when compared with other Mississippian and Upper Devonian shales in north-central Pennsylvania. The authors did not observe any secondary mineralization such as copper bloom that often occurs with sedimentary uranium deposits.

Given the probability that meandering channelways during Huntley Mountain time were more ephemeral, the likelihood of finding cut-off meander deposits and large quantities of fossilized wood and other carbonaceous debris to serve as reducing agents is poor. Since that circumstance is a favorable one for uranium mineralization, the underlying Catskill Formation may be a more desirable target for uranium exploration. However, because the Huntley Mountain has a greater sand content, and because the shale interbeds are thinner and farther apart vertically, the movement of groundwater and processes of uranium mineralization during early diagenesis (formation of roll-type deposits) may have operated with greater ease in the Huntley Mountain than in the Catskill.

Sedimentary concentrations of uranium tend to occur more commonly in feldspathic sandstones that have a granitic provenance. If feldspar is a clue to uranium occurrence, it is worth noting that, although rare, there seems to be more feldspar in Catskill sandstones than in Huntley Mountain sandstones.

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APPENDIX

TYPE SECTION OF THE HUNTLEY MOUNTAIN FORMATION

Part 1. Supplemental Section

Supplement to the main section given in Part 2; includes a better exposure of the Burgoon Sandstone and the upper part of the Huntley Mountain Formation. Located along a jeep trail (Figure 34) ascending the west side of Huntley Mountain, in the Jersey Mills quadrangle, between 41°19′22″N/-77°22′34″W (top) and 41°19′08″N/77°22′37″W (bottom). Measured by T. M. Berg, July 25, 1977.

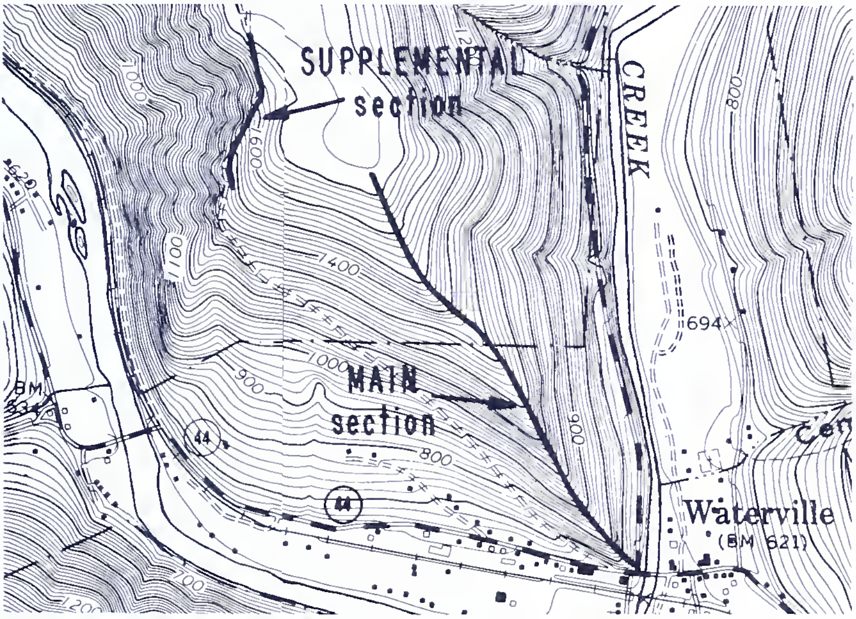

Figure 34. Map showing the location of the type section of the Huntley Mountain Formation (main section and supplemental section). The map scale is 1:24,000.

Unit	Description	Thickness Meters	Thickness Feet
	Top of section.		
	Burgoon Sandstone		
15	Covered. Slope covered with slabby sandstone boulder colluvium. Top of slope is beginning of broad, flat area; assumed near top of Burgoon	7.4	24.3
14	Sandstone, very light gray (N8) to pinkish-gray (5YR8/1), weathering to grayish orange (10YR7/4); medium grained to almost coarse grained; well-sorted quartz grains and few dark minerals set in silica cement and limonite-clay matrix; hard and well indurated, apparently more quartzitic than underlying sandstones; thin bedded; flaggy	3.5	11.5
13	Silt shale, medium-dark-gray (N4), fissile, chippy	1.7	5.6

Unit	Description	Thickness Meters	Feet
12	Sandstone, light-gray (N7) to pale-orange (10YR7/2), weathering to light brown (5YR6/6); well-sorted, subangular to subrounded quartz grains and few dark minerals set in clay matrix and some silica cement; clay matrix stained by limonite; thickly laminated in well-developed parallel bands; slabby	2.6	8.5
11	Clayey silt shale, medium-dark-gray (N4), fissile, chippy; no fossils observed	0.8	2.6
10	Sandstone, medium gray (N5) to medium-light-gray (N6), weathering to light brown (5YR6/4); thin to thick bedded; dominantly medium grained, ranging from fine grained to coarse grained; well sorted; slightly micaceous; more clay matrix than silica cement; well-developed trough cross strata in wedge- or trough-shaped sets varying from 0.3 to 0.8 m (1.0 to 2.6 ft) thick; trough axis at 10.4 m (34 ft) above base oriented N32W; slabby and blocky, sometimes flaggy. Bottom contact covered	26.0	85.3
9	Covered. Steep slope covered with boulder colluvium of sandstone, light-gray (N7) to medium-light-gray (N6), medium-grained, subquartzitic	16.0	52.5
	Total Burgoon Sandstone	58.0	190.3
	Huntley Mountain Formation (part)		
8	Slumped outcrop. Claystone and clay shale, grayish-red (10R4/2) and dark-grayish-red (10R3/2) (wet); very soft, unctuous, and plastic; subfissile to nonfissile; some chippy to hackly fragments; very wet—spring located at this horizon (Patton red shale)	0.5±	1.6±
7	Sandstone grading up through siltstone and silt shale to silty clay shale or claystone (upper 1.0 m, or 3.3 ft); light olive gray (5Y5/2) with greenish tinge; sandstone is very fine grained and micaceous; thinly laminated and planar bedded, containing some ripple bedding; platy to hackly. Clayey siltstone lens contains well-preserved plant fossils (pinnules of *?Adiantites spectabilis* Read, and *?Adiantites* sp. cf. *?A. cardiopteroides* Read). Upper meter is hackly, chippy, and platy; partly covered; contains few unidentified plant fragments. Whole unit has sharp bottom contact	2.7	8.9
6	Sandstone, very light olive gray (5Y6/2), fine-grained, micaceous, thin-bedded; well-developed trough cross strata in broad, wedge-shaped sets ranging from 0.2 to 0.6 m (0.7 to 2.0 ft) thick; forms prominent ledge; sharp bottom contact	1.5	4.9
5	Interbedded sandstone and siltstone or silt shale, occurring as several apparent fining-upward cycles; dominantly sandstone. Sandstone is dusky yellow (5Y6/3), fine grained, micaceous, slabby, flaggy; some spheroidal weathering. Siltstone and silt shale are light olive gray (5Y5/2), micaceous, subfissile to fissile; platy, hackly, and chippy; contain some fossil plant fragments. Uppermost 0.5 m (1.6 ft) is coarse silt shale, very micaceous, thinly to very thinly laminated; displays linguoid ripple bedding having apparent current direction of N2E. Bottom of whole unit covered	14.0	45.9
4	Covered. Sandstone colluvium	2.4	7.9
3	Clayey silt shale grading upward to carbonaceous clay shale; light olive gray (5Y5/2) with greenish cast, grading upward to grayish		

Unit	Description	Thickness Meters	Feet
	black and dark gray (N2 and N3); subfissile to dominantly fissile; thinly laminated to very thinly laminated; lower olive part contains many small unidentified trace fossils that are interpreted as possible burrows (less than 3 mm in diameter); whole unit contains many fossil plant fragments and stems; platy and chippy, grading upward to chippy and flaky. Bottom contact sharp	2.0±	6.6±
2	Sandstone, moderate-yellowish-brown (10YR5/4) with grayish-orange-pink (5YR7/2) tinge, grading upward through very light olive gray (5Y6/2) to moderate yellowish brown (10YR5/4) with dusky-yellow (5Y6/4) tinge; fine grained, grading upward to medium grained; clay matrix in lower part with silica cement increasing upward; hard and subquartzitic at top; clay chips and mudstone clasts up to 2 cm (0.8 in.) in length common at base; medium bedded to dominantly thin bedded; small- to medium-scale trough cross strata in 0.2- to 0.5-m- (0.7- to 1.6-ft-) thick sets that display broad wedge or trough geometry; slabby and flaggy to rubbly. Sharp bottom contact	6.2	20.3
1	Interbedded siltstone, silt shale, sandstone, and sand-silt laminite; interval above 3.5 m (11.5 ft) above base is dominantly sand-silt laminite; light olive gray (5Y5/2) with some dusky yellow (5Y6/4) and light olive brown (5Y5/6), grading to moderate yellowish brown (10YR5/4) near top; micaceous; very thin bedded, grading upward to thickly laminated; fissile and subfissile; chippy, platy, and flaggy; planar bedding and some vague ripple bedding; few fossil plant fragments. Bottom contact covered	5.9	19.4
	Total exposed Huntley Mountain Formation	35.2	115.5

Part 2. Main Section

Main type section; includes the upper 113.3 m (371.4 ft) of the Catskill Formation, all of the Huntley Mountain Formation, and part of the overlying Burgoon Sandstone. Located along a topographic nose (Figure 34) ascending Huntley Mountain above the village of Waterville, in the Waterville quadrangle, between 41°19′09″N/77°22′20″W (top) and 41°18′35″N/-77°21′19″W (bottom). Base of section is at the northwest corner of the road intersection, at the western side of the bridge crossing Little Pine Creek at Waterville. Measured by T. M. Berg and W. D. Sevon, July 12 and 13, 1977.

Unit	Description	Thickness Meters	Feet
	Top of section.		
	Burgoon Sandstone		
57	Covered. Top of interval is top of lower cliff-forming part of Burgoon. Base of interval is at change to steep slope covered by moderate amount of sandstone float. Sandstone is light brown (5YR6/4), fine to medium grained, containing some quartz granules and pebbles (up to 6 mm in diameter); contains some shale		

Unit	Description	Thickness Meters	Thickness Feet
	clasts up to 6 cm (2.4 in.) wide; slabby to rubbly. Sandstone float at top of interval is almost white (N8–N9), weathering to dusky yellow (5Y6/4)	39.2	128.6
	Total lower part of Burgoon Sandstone	39.2	128.6
	Huntley Mountain Formation		
56	Covered. Very gentle slope to broad, flat area. At 1.7 m (5.6 ft) above base of interval is sandstone float, nearly in place in outcrop, very light olive gray (5Y6/2), fine-grained, very thin bedded; linguoid ripples; slabby and platy	5.2	17.1
55	Sandstone, very light olive gray (5Y6/2), weathering to light brown (5YR6/4) to moderate brown (5YR4/4); fine grained to dominantly medium grained; more silica cement than clay matrix; slightly micaceous; one quartz pebble 5 mm in diameter was noted; few clay-chip clasts present; medium to thin bedded upwards; trough cross strata in sets up to 0.4 m (1.3 ft) thick; slabby to blocky. Unit partially covered; bottom contact covered.	4.7	15.4
54	Covered. Interval covered with float of sandstone similar to unit 55	8.7	28.5
53	Sandstone, very light olive gray (5Y6/2) with dusky-yellow tinge; fine grained to dominantly medium grained; subquartzitic; contains scattered shale-chip clasts up to 1 cm (0.4 in.) long; thin to medium bedded; slabby and blocky; bottom contact covered. At 8.7 m (28.5 ft) above base, sandstone is very light olive gray, weathering moderate reddish brown (10R4/6); fine grained; contains fossil plant *(Lepidodendropsis)*. Whole unit partly covered . .	15.6	51.2
52	Covered. Float of mixed gray sandstone and olive-gray siltstone . .	4.3	14.1
51	Interbedded siltstone and silt shale, light-olive-gray (5Y5/2), subfissile to fissile, micaceous; contains fossil plant fragments and invertebrate(?) trails; silt shale is ripple bedded. Unit partly covered; bottom contact covered; unit 51 considered equivalent to lower part of unit 1 of supplemental section (Part 1).	3.5	11.5
50	Covered. Interval covered by float of sandstone, light-olive-gray (5Y5/2), very fine grained, micaceous, ripple-bedded, hackly to rubbly. Trace of grayish-red silt shale float at bottom of interval. At 5.2 m (17.1 ft) above base, float of platy, buff silt shale and very fine grained sandstone. At 6.9 m (22.6 ft) above base, float of light-olive-gray (5Y5/2), clayey silt shale, and brownish-gray (5YR4/1), ripple-bedded, hackly and platy siltstone. At 12.1 m (39.7 ft) above base, float in roots of fallen trees of light-olive-gray (5Y5/2), hackly to rubbly, clayey siltstone. Between 13.8 and 15.6 m (45.3 and 51.2 ft) above base, float in roots of fallen trees is light-olive-gray (5Y5/2), platy siltstone containing burrows(?) . . .	19.5	64.0
49	Covered. Lower few meters flat to very gently sloping, and apparently underlain by sandstone similar to unit 48. At 3.5 m (11.5 ft) above base of interval, float of silt shale, brownish-gray (5YR4/1) to grayish-red (5R4/2); chippy and hackly. Above reddish silt shale float, slope steepens and float of *Cedar Run conglomerate* appears. *Cedar Run* is sandstone and conglomeratic sandstone, yellowish-brown (10YR6/4) and moderate-yellowish-gray		

Unit	Description	Thickness Meters	Feet
	(5Y6/3), weathering to dark yellowish orange (10YR6/6) and medium light gray (N6); fine to very coarse grained, dominantly medium to coarse grained; pebbles are no larger than 1 cm (0.4 in.) and have average diameter between 2 and 5 mm; pebbles are mostly milky and smoky quartz, some lithic fragments and shale clasts, and rare black chert; fair to poor sorting; pebbles are rounded to subrounded, and have generally low sphericity; some linguoid ripples; ripple-drift structure in float near top of unit; rare fossil spiriferid brachiopods; trace fossils (hypichnial ridges 2 to 6 mm in diameter) common on some bedding surfaces; thin to medium bedded; slabby to rubbly	10.4	34.1
48	Sandstone, light-olive-gray (5Y5/2) to dusky-yellow (5Y6/4), fine- to very fine grained; clay matrix and some silica cement; not as quartzitic as underlying units; some limonite in matrix; some beds contain enough clay matrix to yield friable weathering character; micaceous; small-scale trough cross strata in sets 0.1 to 0.3 m (0.3 to 1.0 ft) thick; trough axes oriented S5W, N85W, and N60E; slabby. Bottom contact covered	2.3	7.5
47	Covered. From base to 2 m (6.6 ft) above base, float of brownish-gray (5YR4/1), hackly silt shale. Remainder of interval covered by float of light-olive-gray (5Y5/2), fine- to very fine grained sandstone.	12.8	42.0
46	Siltstone grading up through silt shale and silty clay shale to silty claystone (upper 0.2 m, or 0.7 ft); light olive gray (5Y5/2), grading up through medium olive gray (5Y4/2) to brownish gray (5YR4/1) at top (claystone); subfissile, grading up through fissile, to nonfissile at top; few fossil plants, questionably identified as *Archaeopteris* sp. Sharp bottom contact.	1.7	5.6
45	Sandstone, medium-yellowish-brown (10YR5/2) to moderate-yellowish-brown (10YR5/4), with dusky-yellow cast; fine to very fine grained; some thin, silt-sized zones; planar bedding, and trough cross strata in sets approximately 0.5 m (1.6 ft) thick; trough axis measured N40E; flaggy and slabby. Bottom contact covered.	1.4	4.6
44	Covered. Sandstone float; some ripple-bedded siltstone float	5.2	17.1
43	Sandstone, light-olive-gray (5Y5/2) to dusky-yellow (5Y6/4), fine-grained; contains few scattered clay shale flakes up to 1 cm (0.4 in.) in diameter; thin bedded; planar bedding, and broad trough cross strata in wedge-shaped sets up to 1 m (3.3 ft) thick; few interbeds of buff siltstone or silt shale displaying well-developed linguoid ripple bedding; unit appears to become more siliceous upward; slabby, flaggy, and platy. About 70 percent of unit is partially covered.	14.6	47.9
42	Covered. Float of grayish-red (5R4/2) silt shale; at 6.9 m (22.6 ft) above base, float changes to olive-gray (5Y3/2) shale and sandstone (part of "Mount Pleasant" red-bed horizon)	8.2	26.9
41	Siltstone and clayey silt shale arranged in two fining-upward sequences; brownish gray (5YR4/1); subfissile and fissile; some ripple bedding in siltstone; few fossil plant rootlets in silt shale; micaceous; platy and chippy; sharp bottom contact ("Mount Pleasant" red-bed horizon)	2.2	7.2

Unit	Description	Thickness Meters	Feet
40	Sandstone, light-olive-gray (5Y5/2) to dominantly dusky yellow (5Y6/4); brownish gray (5YR4/1) in upper 0.6 m (2.0 ft); fine to very fine grained, very thin to thin bedded; both planar bedding and broad trough-style crossbedding; trough axis in upper brownish-gray sandstone is oriented S30W; from 0.4 to 0.7 m (1.3 to 2.3 ft) above base is zone of ripple bedding (linguoid ripples) having current direction of S50W; at 4.3 m (14.1 ft) above base, well-developed parting-step lineations oriented N28E, N22E, and N32E; platy to flaggy; sharp bottom contact	4.9	16.1
39	Sandstone, dark-yellowish-brown (10YR4/2) to light-olive-gray (5Y5/2) with yellowish tinge; fine grained, approaching medium grained; large amount of clay matrix; common hematite specks; micaceous; contains small mud-chip clasts in lower 0.3 m (1 ft); very thin bedded; planar bedding; unit fines upward to very fine grained, and has ripple-bedded silt-clay laminite in upper 0.5 m (1.6 ft); abundant fossil plant fragments and stems (replaced by limonite) 2.0 m (6.6 ft) below top; flaggy to platy; gradational bottom contact.	4.9	16.1
38	Intraformational conglomerate; shale clasts ranging in size up to 5 cm (2 in.) wide and 1 cm (0.4 in.) thick, set in sandy matrix; light olive gray (5Y5/2) to yellowish gray (5Y7/2), clayey, noncalcareous; weathers to form recess; contains unidentified plant fragments and stems; sharp bottom contact	0.4	1.3
37	Sandstone, light-olive-gray (5Y5/2) with tinge of dusky yellow (5Y6/4); fine grained, thin bedded, planar bedded; some very low angle, small-scale cross strata in tabular sets up to 0.4 m (1.3 ft) thick; slabby and flaggy. At 3.0 to 3.5 m (9.8 to 11.5 ft) above base is sand-silt laminite, grading up to clayey silt shale; micaceous, ripple bedded. Sharp bottom contact	10.8	35.4
36	Intraformational conglomerate, calcareous; angular shale clasts set in poorly sorted matrix; mottled medium gray (N5) and light olive gray (5Y5/2); weathers brown (due to siderite?)	0.2	0.7
35	Sandstone, light-olive-gray (5Y5/2), fine-grained, very clayey, friable; saccharoidal weathering surface; contains shale clasts up to 4 cm (1.6 in.) long; irregular bedding; few unidentifiable fossil plant fragments; sharp bottom contact	0.4	1.3
34	Interbedded claystone and siltstone, dominantly claystone; slightly silty; olive gray (5Y4/1) to light olive gray (5Y5/2), to light grayish olive (10Y5/2); weathers light brown (5YR6/6); nonfissile to subfissile; thickly laminated, contorted; platy to hackly; sharp bottom contact	0.8	2.6
33	Sandstone, light-olive-gray (5Y5/2) to dark-yellowish-brown (10YR4/2), fine-grained; clay matrix and some silica, hematite, and siderite cement; slightly calcareous; well-developed trough crossbedding and some planar bedding; very flaggy; flags appear thicker on average than those derived from underlying units; bottom contact partially covered	12.7	41.7
32	Siltstone, brownish-gray (5YR4/1) with grayish-red (5R4/2) tinge; subfissile, thickly laminated, micaceous; subtly ripple bedded, having current direction of N55W; platy, chippy; gradational bottom contact. Upper third of unit covered, but grayish-red (5R4/2), fissile, silty clay shale float containing fossil rootlets is common . .	2.7	8.9

Unit	Description	Thickness Meters	Feet
31	Sandstone, light-olive-gray (5Y5/2) to dusky-yellow (5Y6/4), medium-grained; clay matrix; small mud-chip clasts in lower 0.5 m (1.6 ft) weather away, leaving pitted surface; common limonite specks; common fossil plant fragments on some bedding surfaces; thin bedded; low-angle cross strata in sets 0.2 to 0.9 m (0.7 to 3.0 ft) thick; unit forms part of large rock pillar; sharp bottom contact	3.3	10.8
30	Intraformational conglomerate, calcareous; angular shale clasts set in poorly sorted matrix; mottled medium gray (N5) and light olive gray (5Y5/2); sharp bottom contact	0.1	0.3
29	Sandstone, light-olive-gray (5Y5/2), fine- to medium-grained; clay matrix, apparently in slightly greater quantity than in underlying units; slightly micaceous; thickly laminated to thin bedded; planar bedded to broadly crossbedded, having low-angle trough cross strata showing axis orientation of N50W; lower 0.5 m (1.6 ft) has reworked fragments of unit 28; at 6.2 m (20.3 ft) above base, fossil trunk impression, 46 by 23 cm (18 by 9 in.) in size, is preserved. At 2.9 to 3.2 m (9.5 to 10.5 ft) above base is light-olive-gray (5Y5/2) clayey siltstone, nonfissile to subfissile, contorted; contains rare fossil plant fragments and stems; hackly. Sharp bottom contact (disconformity).....................................	8.1	26.6
28	Intraformational conglomerate; angular shale clasts and pisoliths set in poorly sorted, sandy, clayey matrix; calcareous; pisoliths are medium gray (N5), weathering to almost white (N9); matrix is mix of colors, mainly reds and grays; one shale clast measures 28 cm (11 in.) long and 6 cm (2.4 in.) wide, but most shale clasts are less than 4 cm (1.6 in.) long; weathers to a recess; some pisoliths have obvious concentric structure, and are less than 1 cm (0.4 in.) in diameter. Unit disappears laterally as disconformity beneath unit 29 transects down section	0.2	0.7
	Total Huntley Mountain Formation	169.8	557.2
	Catskill Formation (part)		
27	Sandstone, grading up to very coarse siltstone (upper 0.9 m or 3.0 ft); sandstone is medium olive gray (5Y5/1) to olive gray (5Y4/1); siltstone is alternating very dusky red (10R2/2) or medium grayish red (5R3/2) and medium gray (N5); fine grained; clay matrix and silica cement; thin bedded to thickly laminated; trough cross strata in sets ranging from 0.1 to 0.5 m (0.3 to 1.6 ft) thick; trough axis oriented N84W; scattered indistinct zones of gray shale-chip concentration and calcium carbonate; linguoid-rippled siltstone at 3.5 m (11.5 ft) above base, having N15W current direction; slabby, blocky, and flaggy, grading up to platy; bottom contact covered. At top of unit is discontinuous, 0- to 0.1-m- (0- to 0.3-ft-) thick, slightly silty, nonfissile claystone, mottled grayish-red (5R4/2) and olive-gray (5Y4/1), hackly	4.8	15.7
26	Covered. Gentle rise with some grayish-red (5R4/2) siltstone and light-olive-gray (5Y5/2) silt shale float in lower half of interval . . .	2.8	9.2
25	Siltstone, brownish-gray (5YR4/1), subfissile, thickly laminated; ripple bedded in apparent linguoid form; platy, chippy; sharp bottom contact...	1.1	3.6
24	Sandstone, medium-greenish-gray (5GY5/1), grading up through mottled zone streaked with grayish red (5R4/2) to brownish gray		

Unit	Description	Thickness Meters	Thickness Feet
	(5YR4/1) and dark brownish gray (5YR3/1); fine grained, grading up to very fine grained in upper quarter; moderately micaceous; clay matrix and silica cement, with trace of calcite cement; planar bedding and trough cross strata in sets ranging from 0.1 to 0.4 m (0.3 to 1.3 ft) thick; trough axis oriented S28W; some beds display friable weathering character and form recesses; sharp bottom contact	9.4	30.8
23	Intraformational conglomerate, mixed dark-gray (N3) to medium-gray (N5), and greenish-gray (5GY6/1); overall color is light olive gray (5Y5/2); angular shale clasts set in highly calcareous, clayey matrix (almost a limestone); some quartz granules; one shale clast is 2.5 by 4.0 cm (1.0 by 1.6 in.); weathers to soft mass, forming recess having dark-brown color on surface; apparently crossbedded; thickness varies from 0 to 0.35 m (0 to 1.15 ft); sharp bottom contact	0.2	0.7
22	Sandstone, light-olive-gray (5Y5/2), very fine grained, finely micaceous, planar-bedded, platy, flaggy; bottom contact covered	1.2	3.9
21	Covered. Surface covered with olive-gray sandstone float from outcrops above	2.5	8.2
20	Silt shale and siltstone, brownish-gray (5YR4/1) with reddish tinge, thickly laminated; very low angle crossbedding in sets less than 0.1 m (0.3 ft) thick; very finely micaceous; bottom contact covered	2.0	6.6
19	Covered. Mixed reddish siltstone and claystone float	7.7	25.3
18	Silt shale grading up to siltstone; grayish red (5R4/2) to brownish gray (5YR4/1); upper meter (3.3 ft) has ripple-drift structure throughout; lower half meter (1.6 ft) has scattered fossil rootlet structures; chippy and platy, grading up to hackly; bottom contact covered	1.5	4.9
17	Covered. Slope covered by float of reddish siltstone, silt shale, and clay shale; crumbly, flaky, hackly; some fossil rootlets; small flagstone prospect near top of interval	17.8	58.4
16	Siltstone, brownish-gray (5YR4/1), subfissile, thickly laminated, ripple-bedded; common fossil rootlets; platy; bottom contact covered	0.7	2.3
15	Covered	0.5	1.6
14	Siltstone grading up through silty clay shale to claystone; brownish gray (5YR4/1) with grayish-red (5R4/2) tinge, grading up to grayish red (10R4/2); micaceous; thickly laminated, grading up through very thinly laminated to structureless; fossil rootlets common in shale and claystone; platy, chippy, hackly; sharp bottom contact	1.8	5.9
13	Sandstone grading up to siltstone; light olive gray (5Y5/2), grading up to brownish gray (5YR4/1) in upper 3 m (9.8 ft); fine grained, grading up to silt sized; thin bedded to very thin bedded; planar bedded at base, grading up through low-angle, small-scale trough crossbedding in middle; upper meter (3.3 ft) is planar bedded; parting-step lineation near base oriented N45E; parting-step lineation near top oriented N23W; slabby, flaggy, platy; sharp bottom contact. Old flagstone prospect developed in coarse siltstone	4.0	13.1

Unit	Description	Thickness Meters	Feet
12	Sandstone, medium-gray (N5) with tinge of brown, mixed with moderate yellowish brown (10YR5/4); medium to fine grained; clay matrix and silica cement, with trace of calcite; common blebs of limonite; small-scale trough cross strata; one trough axis oriented S46W; contains fairly common fossil plant fragments and stems, and finely comminuted carbonaceous debris; slabby; bottom contact covered	1.2	3.9
11	Sandstone grading up to siltstone (upper 2.8 m, or 9.2 ft); medium yellowish gray (5Y7/2), grading up to brownish gray (5YR4/1); fine to almost medium grained, grading up through very fine grained to silt sized; thin bedded, grading up through very thin bedded and thickly laminated to thinly laminated at top; low-angle trough cross strata in small-scale sets ranging from 0.1 to 0.3 m (0.3 to 1.0 ft) thick. From 3.5 to 4.3 m (1.1 to 1.3 ft) above base, well-developed ripple bedding (in-drift) exposed, having current direction of S74W. Whole unit displays natural fragmentation grading from flaggy and slabby up through platy to hackly and chippy. Bottom contact covered	9.7	31.8
10	Covered. Slope covered with float of siltstone and clayey silt shale, brownish-gray (5YR4/1), grayish-red (5R4/2 and 10R4/2), and dark-reddish-brown (10R3/4); some fossil rootlets(?); finely micaceous; chippy and hackly	10.8	35.4
9	Siltstone and silt shale, grayish-red (5R4/2) to brownish-gray (5YR4/1), subfissile, thickly laminated, micaceous; linguoid(?) ripple bedding having current direction of N10W; chippy, hackly, platy; 50 percent covered; bottom contact sharp	1.5	4.9
8	Sandstone, light-olive-gray (5Y5/2) to medium-olive, with reddish tinge in upper third; medium to dominantly fine grained, grading up to very fine grained; very thin to thin bedded; micaceous; several thin lenses containing fine shale chips and flakes; planar bedding and trough crossbedding; trough cross strata in sets 0.1 to 0.5 m (0.3 to 1.6 ft) thick having trough axes oriented from S10W to N70W; flaggy and slabby to platy; sharp bottom contact.	3.5	11.5
7	Interbedded siltstone and silt shale, and some silty clay shale; grayish red (5R4/2 and 10R4/2) to brownish gray (5YR4/1), fissile to subfissile, very thinly laminated to thin bedded; micaceous; dominantly planar bedded, but has some vague linguoid(?) ripple bedding and very small scale trough crossbedding; flaky, hackly, chippy, slabby; upper half of unit partly covered; sharp bottom contact	8.2	26.9
6	Sandstone, light-olive-gray (5Y5/2), grading up to brownish gray (5YR4/1) and moderate grayish brown (5YR4/2); fine grained to almost medium grained; micaceous, especially in upper third; low-angle, small-scale crossbedding with some planar interbeds; apparent crossbed vectors range between west and N25W; slabby, grading up to flaggy; sharp bottom contact	6.8	22.3
5	Siltstone to sandstone, light-olive-gray (5Y5/2), weathering to light brown (5YR5/6); silt sized to very fine grained; thinly laminated; fissile to slightly subfissile; micaceous; common limonite flecks; common to abundant fossil plant fragments and stems; ir-		

Unit	Description	Thickness Meters	Thickness Feet
	regularly planar bedded; chippy to platy; sharp to slightly gradational bottom contact	0.5	1.6
4	Sandstone, light-olive-gray (5Y5/2) to medium-olive-gray (5Y4/2), fine- to medium-grained, thickly laminated to very thin bedded, micaceous, somewhat friable; small-scale trough cross-bedding, and planar bedding (upper half); slabby, flaggy; sharp bottom contact	3.5	11.5
3	Sandstone, dusky-yellow (5Y6/4) to light-olive-gray (5Y5/2), medium-grained to dominantly fine grained, thin bedded; very gently crossbedded in lower half of unit; convolute bedding in upper half of unit; fossil plant fragments and finely comminuted carbonaceous debris on some bedding planes; weathered surface has friable aspect; flaggy, slabby; sharp bottom contact	2.3	7.5
2	Intraformational conglomerate; angular shale clasts set in calcareous claystone or very clayey limestone; medium greenish gray (5GY5/1), nonfissile, thin to medium bedded, micaceous, laterally discontinuous; contains sandstone and siltstone lenses; pitted weathering surface; rubbly to blocky; sharp bottom contact	1.8	5.9
1	Siltstone, grading up through silt shale and clay shale to silty claystone and claystone; grayish red (5R4/2) and brownish gray (5YR4/1), and medium greenish gray (5GY5/1) in top 0.5 m (1.6 ft); variable fissility; grossly fining upward, having some internal fining-upward subunits; micaceous; vague ripple bedding; fossil rootlets common at 2.1 m (6.9 ft) above base; thinly laminated to nonbedded; platy, chippy, hackly. Base of unit is at road level . . .	5.5	18.0
	Total Catskill Formation measured	113.3	371.4

REFERENCE SECTIONS AND OUTCROPS OF THE HUNTLEY MOUNTAIN FORMATION

7-1/2-minute quadrangle	*Approximate location and comments*	*Base of section or outcrop location Latitude Longitude*	*Top of section Latitude Longitude*
Antrim	In streambed of Wilson Creek; shows pisolithic breccia, crossbedding, ripple bedding, and plant fossils. Excellent outcrop along Pa. Route 287 approximately 3.5 miles (5.6 km) north of Morris, Pennsylvania.	41°38′20″N 77°18′04″W	—
Barbours	Along west bank of Loyalsock Creek; below bridge at Barbours. Good outcrops of calcareous sandstone at base of Huntley Mountain.	41°23′36″N 76°48′03″W	—
Barbours	Coal Mine Hollow; mostly float, but good outcrops of the Burgoon, containing conglomerate, to contrast with underlying Huntley Mountain.	41°24′27″N 76°48′32″W (Bottom of *exposed* Huntley Mountain; *not* bottom of formation)	41°24′18″N 76°49′25″W
Bodines	Section exposed along nose of Sullivan Mountain.	41°28′52″N 76°58′10″W	41°29′16″N 76°57′22″W
Cammal	Along road from Lebo Vista to Trout Run Road, southwest of Cammal. Scattered outcrops.	41°23′53″N 77°28′41″W	41°23′29″N 77°28′23″W
Cammal	Nose west of Truman Run; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); about 30 percent exposure, mainly in lower part.	41°23′11″N 77°26′38″W	41°23′33″N 77°26′53″W
Cammal	Nose west of Wolf Run; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); 30 to 40 percent exposure. Burgoon not encountered at top of section.	41°26′05″N 77°29′38″W	41°26′29″N 77°29′47″W
Cammal	Nose northwest of Cammal (west of Mill Run); section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 30 percent exposure, mostly above Cedar Run conglomerate.	41°24′29″N 77°27′57″W	41°24′53″N 77°28′05″W

7-1/2-minute quadrangle	*Approximate location and comments*	*Base of section or outcrop location Latitude Longitude*	*Top of section Latitude Longitude*
Cedar Run	Nose north of Stone Quarry Run (about 1 mile (1.6 km) north of Blackwell); section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 50 percent exposure below Cedar Run conglomerate; no information above.	41°34′24″N 77°22′54″W	41°34′43″N 77°22′36″W
Cedar Run	Spur east of Bull Run; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 75 percent exposure of strata above Catskill; mostly float above horizon of Cedar Run conglomerate.	41°32′14″N 77°25′40″W	41°32′25″N 77°25′45″W
Cogan Station	Nose of Hanlon Mountain east of Daugherty Run; cited as one of the best exposures in this quadrangle by R. B. Wells in Faill and others (1977, p. 13); referred to informally as "lower member, Pocono Formation."	41°21′45″N 77°05′09″W	41°21′58″N 77°05′09″W
English Center	Scattered outcrops and float, which is nearly in place in outcrop, along English Run Road and Limbaugh Road.	41°22′46″N 77°18′39″W	41°22′35″N 77°18′19″W
English Center	Section along Schoolhouse Road; measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 30 percent exposure of Huntley Mountain Formation, mostly below horizon of Cedar Run conglomerate.	41°24′12″N 77°21′18″W	41°24′28″N 77°21′30″W
Glen Union	Nose above west bank of West Branch Susquehanna River, opposite Glen Union; section measured by Ebright and Gouse (Ebright, 1952, p. 26-27); also measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 70 percent exposure, starting about 90 feet (27 m) below Cedar Run conglomerate.	41°15′01″N 77°36′39″W (Bottom of *exposed* Huntley Mountain; *not* bottom of formation)	41°15′04″N 77°36′46″W

Glen Union	Excellent outcrop along Pa. Route 120; exposure particularly important because of abundant and well-developed pisoliths in calcareous breccia; largest pisolith observed was 10 cm (4 in.) in diameter.	41°15′07″N 77°36′44″W	—
Hillsgrove	Nose south of Hillsgrove, above Pa. Route 87; section measured by William Ussler for senior thesis at Bucknell University, April, 1973; less than 20 percent exposure.	41°26′15″N 76°42′37″W	41°26′05″N 76°42′19″W
Jersey Mills	Nose east of English Run, crossing Sinking Springs Road, about 1.2 miles (1.9 km) south of Jersey Mills; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); less than 50 percent exposure of Huntley Mountain Formation.	41°20′08″N 77°24′38″W	41°20′24″N 77°24′35″W
Jersey Mills	Exposures along Plantation Trail, about 2.7 miles (4.3 km) south of Jersey Mills; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); less than 10 percent exposure of Huntley Mountain Formation.	41°19′07″N 77°24′59″W (Bottom of *exposed* Huntley Mountain; *not* bottom of formation)	41°19′28″N 77°24′32″W
Jersey Mills	Exposures along Torbert Trail 1/4 mile (0.4 km) north of Jersey Mills; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 50 percent outcrop, mostly above position of Cedar Run conglomerate.	41°21′48″N 77°24′20″W	41°21′46″N 77°24′03″W
Jersey Mills	Nose northwest of mouth of Upper Pine Bottom Run, above Pa. Route 414; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); less than 30 percent exposure of Huntley Mountain Formation, mostly below position of Cedar Run conglomerate.	41°19′16″N 77°23′18″W	41°19′21″N 77°23′37″W
Leroy	Exposures along creek flowing north from Holcomb Pond, 1-1/4 miles (2 km) south of Leroy; includes units 49 through 89 (and above) of "Sunfish" Formation of Woodrow (1968).	41°39′41″N 76°42′04″W	41°39′28″N 76°41′48″W
Lock Haven	Exposures along West Branch Susquehanna River, and up nose just northwest of mouth of Queens Run; part of section below Cedar Run conglomerate covered by surficial materials in Queens Run. Excellent exposure of Huntley Mountain-Catskill contact.	41°10′28″N 77°28′40″W	41°10′43″N 77°28′59″W

7-1/2-minute quadrangle	*Approximate location and comments*	*Base of section or outcrop location Latitude Longitude*	*Top of section Latitude Longitude*
Montoursville North	Nose ascending Allegheny Ridge, west of Loyalsock Creek, 1-1/2 miles (2.4 km) north-northwest of Loyalsockville.	41°20′20″N 76°55′24″W	41°20′23″N 76°55′35″W
Morris	Intermittent outcrops along Rattler Mine Road, starting about 1/2 mile (0.8 km) northwest of Morris.	41°36′05″N 77°17′54″W	41°36′33″N 77°18′10″W
Pottersdale	Intermittent outcrops along switchback road ascending from Spruce, along West Branch Susquehanna River.	41°08′57″N 78°00′04″W	41°09′25″N 78°00′26″W
Powell and Leroy	Intermittent outcrops along road ascending Coal Run northwest of Barclay Station.	41°38′08″N 76°36′50″W (Powell quadrangle—bottom of *exposed* Huntley Mountain; *not* bottom of formation)	41°38′50″N 76°37′32″W (Leroy quadrangle)
Powell	Intermittent outcrops and one flagstone quarry along road to Barclay, ascending mountain south of Towanda Creek, about 1-3/4 miles (2.8 km) southwest of Franklin Center.	41°41′11″N 76°35′47″W	41°40′43″N 76°36′29″W
Ralston	Closely spaced outcrops along private road ascending Red Run just northwest of Ralston.	41°30′39″N 76°57′12″W	41°30′45″N 76°57′45″W
Ralston	Exposures ascending Cascade Run, starting just above road crossing Cascade Run about 0.8 mile (1.3 km) southeast of Newelltown.	41°34′29″N 76°54′04″W	41°34′10″N 76°54′10″W
Ralston	Exposures in bed of Rock Run, continuing up Hawk Run tributary, and up bluff east of Hawk Run.	41°30′24″N 76°55′57″W	41°32′56″N 76°52′37″W
Renovo East and Glen Union	Section exposed on nose north of Huff Run, about 0.7 mile (1.1 km) east of Hyner; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); also measured by Ebright and Ingham (1951, p. 33-35).	41°19′54″N 77°37′22″W (Renovo East quadrangle)	41°20′23″N 77°36′34″W (Glen Union quadrangle)

Sabinsville	Roadcut along west side of Pa. Route 349, 2.6 miles (4.2 km) north of Gaines. Good exposure of fining-upward cycle with shale at top containing possible Mississippian flora.	41°47′16″N 77°34′05″W	—
Salladasburg	Exposures on east side of Larrys Creek, and up topographic nose north of Pond Hollow; includes several small flagstone prospects.	41°19′29″N 77°11′19″W	41°19′47″N 77°11′03″W
Salladasburg	Intermittent outcrops along road ascending to Coal Mountain on west side of Hoagland Run.	41°21′01″N 77°07′55″W	41°21′46″N 77°08′04″W
Slate Run	Flagstone quarry; excellent exposure of fining-upward cycle in Huntley Mountain Formation below horizon of Cedar Run conglomerate.	41°29′26″N 77°30′37″W	—
Slate Run	Topographic nose west of Slate Run (creek), approximately 2 miles (3.2 km) north-northwest of Slate Run (town); section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 20 percent exposure, mostly below level of Cedar Run conglomerate.	41°29′40″N 77°31′14″W	41°29′50″N 77°31′34″W
Slate Run	Series of exposures along long topographic nose dividing Slate Run and Little Slate Run; less than 30 percent outcrop, mostly below horizon of Cedar Run conglomerate.	41°28′28″N 77°31′00″W	41°29′04″N 77°31′34″W
Slate Run	Series of small flagstone quarries and intermittent outcrops along switchback road ascending mountain north of Naval Run, approximately 2.6 miles (4.2 km) west-southwest of Slate Run (town).	41°27′38″N 77°33′04″W	41°27′52″N 77°34′00″W
Slate Run	Outcrop of Cedar Run conglomerate on west side of road near headwaters of Left Branch Hyner Run, just north of spot elevation 1650.	41°25′55″N 77°35′56″W	—
Trout Run and Bodines	Intermittent outcrops along road ascending Bodine Mountain from valley of Grays Run.	41°27′03″N 77°00′44″W (Trout Run quadrangle)	41°27′40″N 76°59′54″W (Bodines quadrangle)
Troy	Outcrops along road ascending Armenia Mountain, mostly in lower two thirds of Huntley Mountain Formation; excellent outcrops also located in gorge of Case Glen just north of road.	41°46′35″N 76°50′20″W	41°46′34″N 76°51′26″W
Waterville	Topographic nose east-northeast of Little Pine Dam; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); less than 10 percent exposure.	41°21′22″N 77°20′59″W	41°21′39″N 77°20′40″W

7-1/2-minute quadrangle	*Approximate location and comments*	*Base of section or outcrop location Latitude Longitude*	*Top of section Latitude Longitude*
Waterville	Topographic nose north of Parker Hollow; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); 20 to 30 percent exposure, mostly above horizon of Cedar Run conglomerate.	41°20′20″N 77°21′37″W	41°20′39″N 77°21′04″W
Waterville	Topographic nose south of Conner Trail; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 30 percent exposure.	41°19′49″N 77°21′50″W	41°19′46″N 77°22′07″W
Waterville	Topographic nose north of mouth of Dam Run; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 15 percent exposure.	41°19′41″N 77°21′20″W	41°19′53″N 77°21′08″W
Waterville	Topographic nose 0.6 mile (1 km) south of Waterville, north of unnamed tributary of Pine Creek; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); approximately 15 percent exposure.	41°18′01″N 77°21′39″W	41°17′52″N 77°22′02″W
Waterville	Exposures along pipeline running east-west, south of Bonnell Run; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); good fossil plants and some conchostracans found in this section.	41°16′14″N 77°20′23″W	41°16′14″N 77°20′48″W
Waterville	Topographic nose at southwest end of Puterbaugh Mountain; section measured by G. W. Colton (Pennsylvania Geological Survey and U. S. Geological Survey files); 20 to 30 percent exposure, mostly below level of Cedar Run conglomerate.	41°17′08″N 77°15′55″W	41°17′30″N 77°15′33″W
West Pike	Intermittent outcrops along road ascending unnamed tributary of Losey Run, beginning approximately 1 mile (1.6 km) south-southwest of Telescope. Burgoon Sandstone absent here; top of Huntley Mountain Formation is pre-Pottsville unconformity.	41°46′10″N 77°44′59″W	41°45′34″N 77°44′46″W (Top of *exposed* Huntley Mountain; *not* top of formation)
Young Womans Creek	Intermittent outcrops along Sevenmile Road.	41°25′44″N 77°39′04″W	41°26′10″N 77°37′45″W